

THIS SUMMER'S DARING VOYAGE TO THE TITANIC | BY TONY PERROTTET

PLUS: Mexico's Greatest Living Artist | BY PAUL THEROUX • T. Rex: Still the Chompian! | BY PAIGE WILLIAMS

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WHAT YOU DIDN'T KNOW ABOUT THE

APOLLO 11 MISSION 50 YEARS AGO

BY CHARLES FISHMAN

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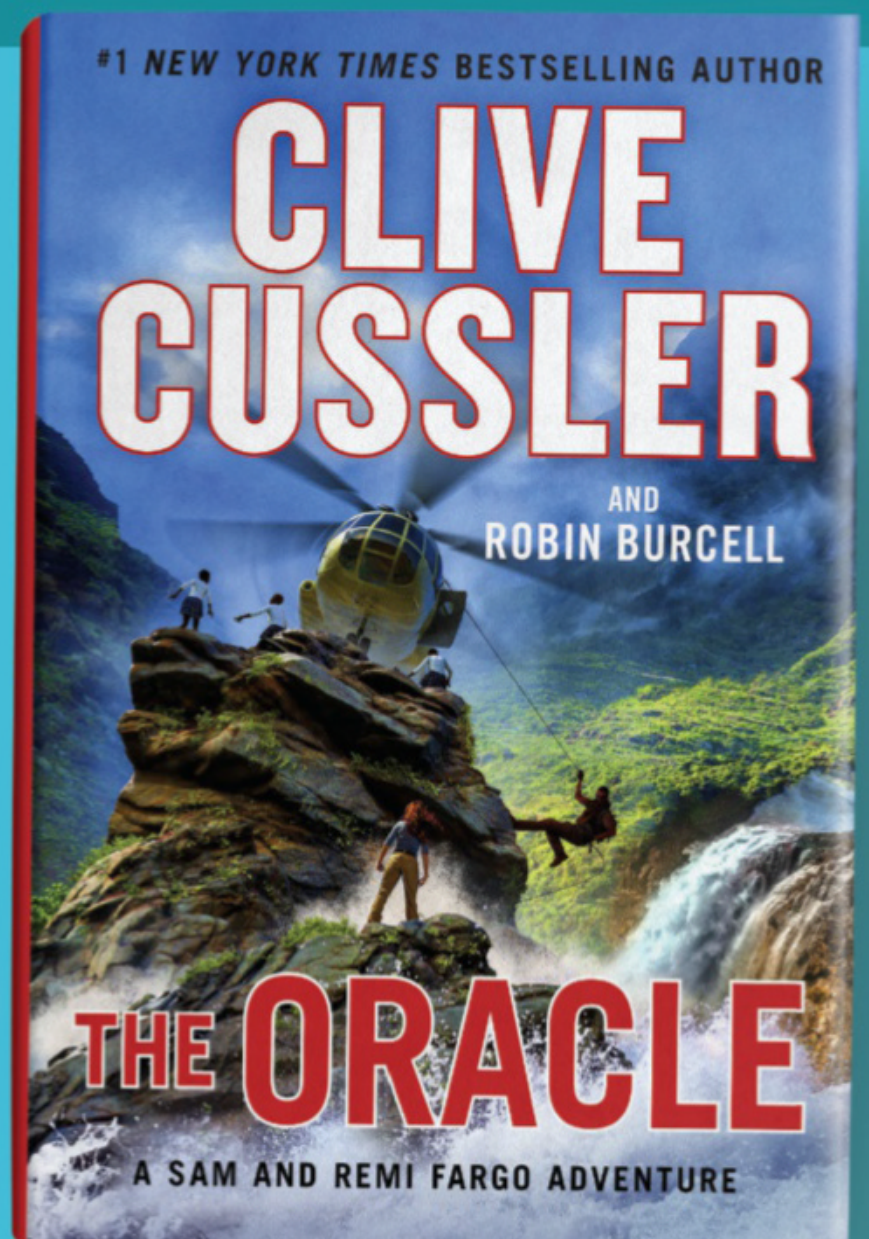
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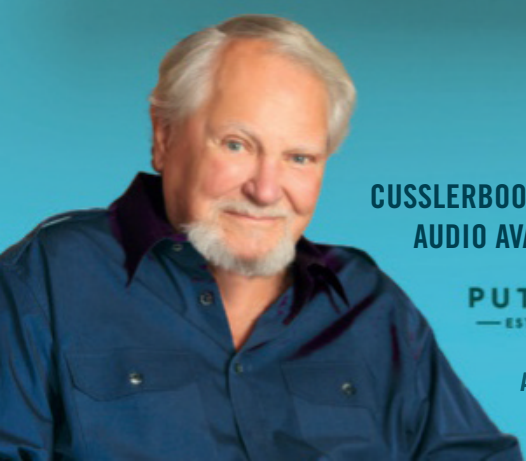
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Smithsonian

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America's Greatest Adventure

On the 50th anniversary of the Apollo 11 mission, here's a surprising inside look at the historic effort to land a man on the Moon, from JFK's secret doubts to Soviet gamesmanship
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El Maestro

Our correspondent sits down for a rare interview with Mexico's greatest living artist, the rebellious Francisco Toledo, who is still mixing paints with a spirit of protest at 78 years of age
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The popular Red Rock Pool, near Santa Barbara, is one of several swimming holes along the Santa Ynez River.

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When temperatures soar, follow the locals to their favorite hidden swimming hole and take the plunge
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Return to the Titanic

This summer the entrepreneur behind the only commercial deep-diving submersible plans to take paying customers to the world's most famous shipwreck
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You've got questions, we've got experts

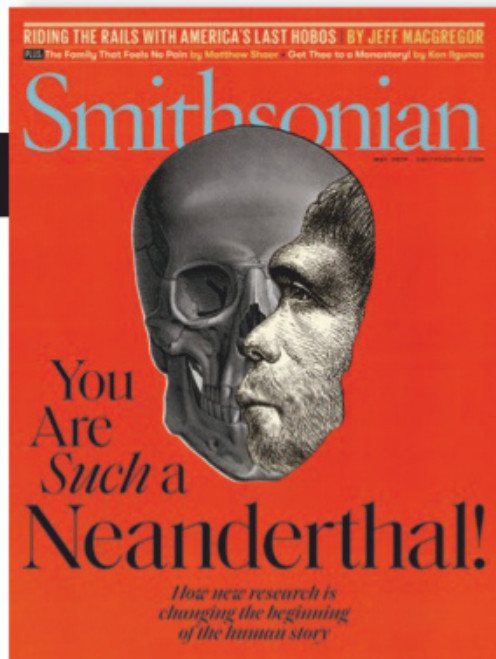
Cover: This lunar extravehicular visor assembly, **photographed by Cade Martin** at the National Air and Space Museum's Udvar-Hazy Center, was worn by Neil Armstrong on the Moon in July 1969.

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FROM THE EDITORS

OUR COVER STORY in May upended conventional wisdom on Neanderthals, whom our species has looked down upon for centuries. Kelsie Spears Johnson welcomed new research that is revealing “they had a lot more to offer than we realized. I’m so excited to see more information pushing against those Neanderthal norms!” Diane Alexander of Buena Vista, California, called the piece “eye-opening,” noting that it “prompted me to think of just how ancient the us-versus-them mentality is that it still exists on our planet. Why must we be so judgmental and disdainful toward people who aren’t exactly like ourselves?” Terry Phelan disagreed with our Prologue graphic on recreating a ninth-century monastery, which noted that the church towers had no practical purpose: “In an era before road maps, highways and GPS, those towers would have been essential for travelers to locate the monastery.”

Hobo History

“The Last of the Great American Hobos” is some of the most lyrical and interesting writing I’ve seen in ages. Jeff MacGregor really captures the feel of a world and group of people most Americans will never know. Great work, Jeff.

— **Doug Verdier** | Minneapolis, Minnesota

Jeff MacGregor’s profile of hobo culture is as satisfying a piece of journalism as anything you’ll read east

or west of Britt. The opening and closing paragraphs are lyrical without being maudlin. The reportage in between is evocative, alive, perfectly measured.

— **Mark Wilson Kimble** | York, Maine

Though his article is well written and engaging, Jeff MacGregor doesn’t get any props for glorifying the hobo lifestyle. If it wasn’t for those pesky little things called personal accountability and bills, not to mention taxes and family, I’d probably enjoy being care-free and bereft of responsibilities too.

— **Douglas J. Gladstone** | Wilton, New York

Unlike Britt, Iowa, residents, folks in my hometown of Jamestown, North Dakota, didn’t welcome hobos. My dad, two brothers and I worked for the Northern Pacific and knew Frank, the NP yard bull [security officer]. Despite the fact that Jamestown was the birthplace of the western author Louis L’Amour, a world-famous hobo, residents rarely provided hobos food, clothing, shelter or medical assistance. Sad.

— **Robert Brake** | Ocean Park, Washington

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No Pain, Yes Gain

The potential for gene therapy is enormous for those with ongoing, debilitating pain (“A Mystery in the Family”). The family members who provided their genome information and the scientists working on this project are to be commended for their persistence in finding an answer for those with life-altering chronic pain.

— **Carol Chisholm** | Nanaimo, British Columbia

Corrections: In “The Myth of Fingerprints” (April), we said that at least 23 people in the U.S. had been imprisoned after being wrongly connected to crime-scene prints. Though all 23 were accused, they were not all convicted.

CONTACT US

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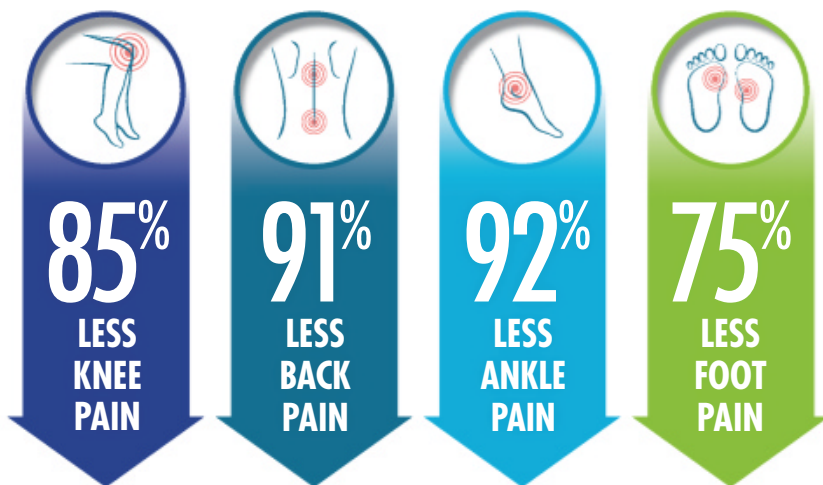
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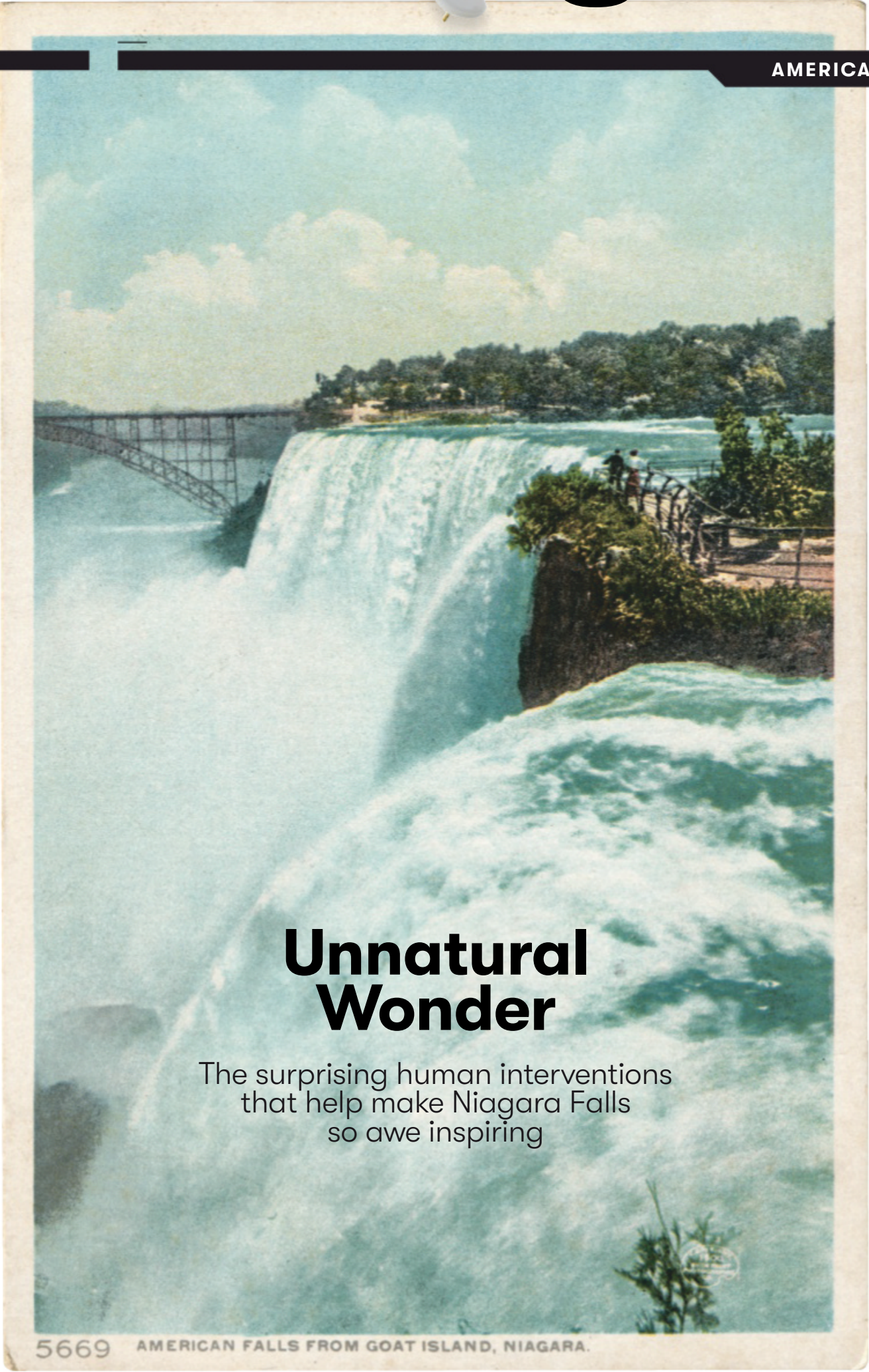
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THE PAST IS

prologue

By
Ben Crair

AMERICAN ICON



Unnatural Wonder

The surprising human interventions
that help make Niagara Falls
so awe inspiring

▲ An early 1900s postcard shows American Falls as it looked before two massive rock slides.



NIAGARA FALLS HAS seen plenty of dramatic stunts over the centuries, ever since a local hotel owner sent a condemned ship with a “cargo of ferocious animals” over the falls in 1827. (Only the goose survived the plunge.) But no feat has attracted more visitors than a scientific survey conducted in 1969. That year, the U.S. Army Corps of Engineers turned off American Falls. The engineers wanted to find a way to remove the unseemly boulders that had piled up at its base since 1931, cutting the height of the falls in half. But the study itself proved more appealing than any improvement they could recommend. The first weekend after the “dewatering,” about 100,000 people showed up to see this natural wonder without its liquid veil.

The performance will have an encore at some point in the coming years when New York State once again dewateres American Falls. The purpose this time is more pedestrian—to replace two bridges—but the process will be the same. Engineers will construct a dam between the American bank of the Niagara River and the eastern tip of Goat Island, stopping the flow of water—nearly 76,000 gallons every second—over the 11-story drop.

Will crowds show up this time? Photos from 1969 suggest the bedrock is nothing special to behold. Without water, American Falls is merely a cliff. And yet the spectacle fulfills a fantasy older than the American nation: human mastery over nature. To sap the falls completely would seem to be the ultimate triumph—but, in fact, Niagara Falls was long ago brought to heel.

The falls—American Falls, Horseshoe Falls and the small Bridal Veil Falls—formed some 12,000



Until engineers constructed the temporary dam in 1969 (above), no one had seen the bare rock face of American Falls since March 30, 1848, when an ice jam from Lake Erie stopped the Niagara River.

years ago, when water from Lake Erie carved a channel to Lake Ontario. The name Niagara came from “Onguiaahra,” as the area was known in the language of the Iroquois people who settled there originally. After the French explorer Samuel de Champlain described the falls in 1604, word of the magnificent sight spread through Europe.

A visit to Niagara Falls was practically a religious experience. “When I felt how near to my Creator I was standing,” Charles Dickens wrote in 1842, “the first effect, and the enduring one—instant lasting—of the tremendous spectacle, was Peace.” Alexis de Tocqueville described a “profound and terrifying obscurity” on his visit in 1831, but he also recognized that the falls were not as invincible as they seemed. “Hasten,” Tocqueville urged a friend in a letter, or “your Niagara will have been spoiled for you.”

To many, these cataracts were not natural wonders but natural resources. When Tocqueville visited, factories already encroached on the water’s edge. In 1894, King C. Gillette, the future razor magnate, predicted Niagara Falls could become part of a city called Metropolis with 60 million people. A few years later, Nikola Tesla designed one of the first hydroelectric plants near the falls. He saw it as a high point in human history: “It signifies the subjugation of natural forces to the service of man.”

Niagara Falls today is the result of the push and pull of exploitation and preservation. The Free Niagara Movement successfully lobbied to create a park around the site in the 1880s, but the changes continued. In 1950, the United States and Canada decided to divert 50 percent of the water from Niagara Falls through underwater tunnels to hydro-

**“HASTEN,”
TOCQUEVILLE URGED
A FRIEND IN A LETTER,
OR “YOUR NIAGARA
WILL HAVE BEEN
SPOILED FOR YOU.”**



electric turbines during peak tourist hours. At night, the water flow over the falls is cut in half again. (Engineers manipulate the flow using 18 gates upstream.)

The historian Daniel Macfarlane has called the modern falls “a completely man-made and artificial cataract.” Ironically, this has maintained them as a tourist attraction. People want to see the image they recognize from postcards, but the Niagara Falls, left to its own devices, is one of the fastest-eroding falls in the world. It has moved seven miles since it formed; the diversion of water has helped reduce the rate of erosion by more than 85 percent.

The engineers who built the diversion tunnels also made several modifications to the actual falls. They excavated both edges of Horseshoe Falls to create a

visually pleasing crest. The 1969 dewatering was another aesthetic intervention, but the engineers decided, surprisingly, to leave the fallen boulders alone. “Recent emphasis on environmental values has raised questions about changing natural conditions even for demonstrated natural and measurable social benefits,” they wrote in their final report.

At some point, the United States and Canada will face the same dilemma again: Do they intervene to maintain the falls or let natural processes unfold? Even with the decreased rate of deterioration, the falls regress a little every year. In about 15,000 years, the cliff edge will reach a riverbed of soft shale—and then Nature will upstage any human efforts. Niagara Falls will crumble and irrevocably disappear. ♦

1

Rock slides in 1931 and 1954 left more than 250,000 tons of shale and dolomite at the base of the falls; engineers wanted to study how it might be removed.



2

To turn off the cataract, bulldozers and dump trucks, fighting a ten-mile-per-hour current, pushed 27,800 tons of earth across the 600-foot-wide river.



3

Instead of diverting the water to Horseshoe Falls, engineers used the International Control Dam to redirect more than 59,000 gallons per second to hydroelectric plants.



CATARACT SURGERY

ONE JUNE DAY 50 YEARS AGO, ENGINEERS TACKLED A SEEMINGLY IMPOSSIBLE FEAT—TURNING OFF AMERICAN FALLS



4

With the river slowed to a trickle, a sprinkler system kept the rock face of the American Falls wet to prevent heat and wind damage.



5

A crane dangling an eight-foot-wide cage lowered workers to the cliff face to remove loose boulders and install meters to measure rock movement.



6

After six months of topographic, geological and seismic studies of the dry falls, engineers decided to leave the rocks at the base. (Two corpses found there were removed.)



PRIDE AND PREJUDICE

Interpreting the legacy
of the Stonewall uprising
50 years later



IT BEGAN AS just another Friday night at the Stonewall Inn, a popular New York gay bar. The raid by the NYPD Public Morals Squad in the early hours of June 28, 1969, would have been routine, too—except this time, tired of harassment, the bar’s patrons fought back. The unplanned uprising launched the gay rights movement, but 50 years later, “Stonewall is one of those events that’s both remembered and misremembered,” says Carmen Hermo, co-curator of “Nobody

▲
Artist Felipe Baeza uses everything from paint to twine and glitter to create memorable images of “invisible bodies,” the people often overlooked by history.

Promised You Tomorrow” at the Brooklyn Museum. The exhibition looks at Stonewall’s legacy through the work of LGBTQ artists born after 1969. From reverent tributes to that night’s forgotten trans heroines to posters parodying the prejudice that sexual and gender minorities still face, these artists pick at the threads of an unfinished historical narrative. “It’s a moment of celebration, but also of reflection,” says Felipe Baeza, whose mixed-media image (above) honors queer love in times of struggle. “We still have a lot of work to do.” ♦

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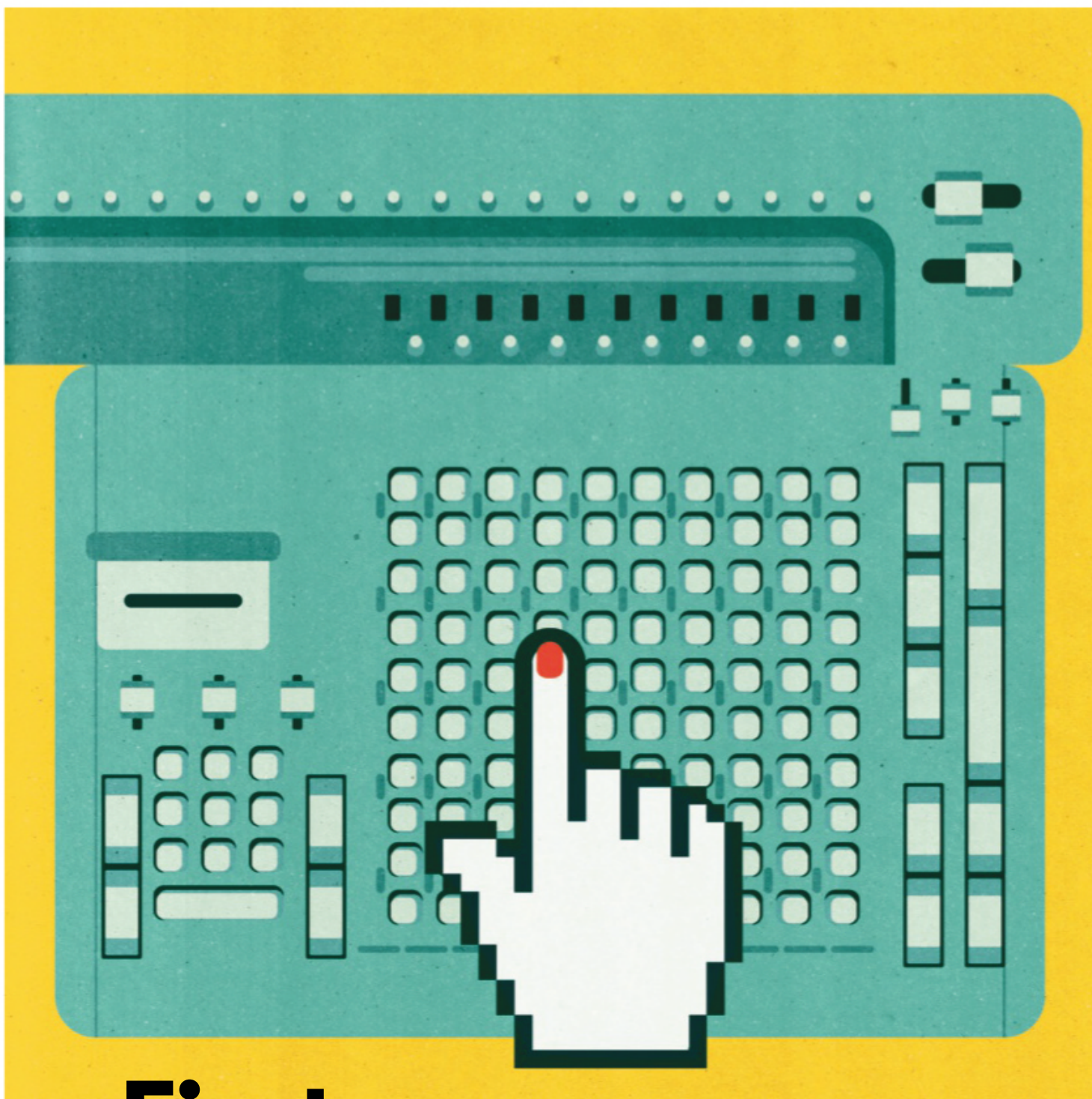
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PRIORITY:YOU





The First Computers Were Human

It's ironic that women today must fight for equality in Silicon Valley. After all, their math skills helped launch the digital age

T

RACY CHOU IS A 31-YEAR-OLD programmer—and “an absolute rock star,” as her former boss Ben Silbermann, the CEO and co-founder of Pinterest, once gushed to me.

She's a veteran of some of Silicon Valley's biggest names. She interned at Google and Facebook, then was an early hire at the question-answering site Quora, where she coded key early features, like its rank-

ing algorithm and its weekly emailer software. At Pinterest, she helped overhaul the entire code base, making the service speedier and more reliable. These days, she's the founder ➔



1977.
Your first real responsibility
drooled a lot. Which seems
pretty manageable compared
to having kids in college and
aging parents to care for in
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of Block Party, a start-up making tools to help social-media users deal with harassment.

Yet for all her street cred, Chou still finds herself grappling with one of the biggest problems in the industry: Female programmers are regarded skeptically, and sometimes even treated with flat-out hostility.

She's seen the same patterns of behavior personally during her decade in coding: colleagues who doubt women's technical chops, or who muse openly about whether women are biologically less wired to be great programmers. She has watched as women linger in jobs while men of equal or lesser ability get promoted; at other firms, she's heard of tales of flat-out harassment, including on-site propositions for sex. Chou's even subject to skepticism herself: Recently she was trying to hire a coder for her new start-up, when the guy accidentally sent her a diary in which he'd meticulously written complaints about her skills.

"He felt I was immature and awkward and very sensitive, and not good with people—in over my head," she says. And this from a guy trying to get her to hire him.

Not everyone in the field is antagonistic to women, of course. But the treatment's bad enough, often enough, that the number of women coders has, remarkably, regressed over time, from about 35 percent in 1990 to 26 percent in 2013, according to the American Association of University Women.

Chou and others are working hard to change things. She has co-founded groups like Project Include that encourage diversity in computer science, while another initiative lobbies venture capital firms to set up anti-harassment policies. "I think we're getting better, but very slowly," Chou tells me.

There's a deep irony here—because women were in computing from its earliest days. Indeed, they

▲ Katherine Johnson (right, in 1962) calculated John Glenn's trajectory. Other women (left, at NACA in 1949 and center, at NASA in 1955) gathered air pressure data.

were considered essential back when "computers" weren't even yet machines. Just before the digital age emerged, computers were *humans*, sitting at tables and doing math laboriously by hand. Yet they powered everything from astronomy to war and the race into space. And for a time, a large portion of them were women.

THE RISE OF HUMAN COMPUTERS began in the early hunt for Halley's comet. The astronomer Edmond Halley had predicted that the celestial body would return and that the laws of gravity could predict precisely when. But those calculations would be too complex and brutal a task for any single astronomer.

So the French mathematician Alexis-Claude Clairaut decided to break the work up—by dividing the calculations among several people. In 1757, he sat down with two friends, the young astronomer Jérôme-Joseph Lalande and Nicole-Reine Lepaute, a clockmaker's wife with a penchant for numbers. At the time, women had little opportunity in science, but Lalande "loved women, especially brilliant women, and promoted them in both word and deed," the historian Ken Alder has written. After arduous weeks of cranking away, the trio predicted that the comet's closest approach to the sun would be between March 15 and May 15 the next year. They were slightly off—the comet rounded the sun on March 13, two days early—but it was the most accurate forecast yet. The age of human computers began.

And not a moment too soon. By the 19th century, scientists and governments were beginning to collect reams of data that needed to be processed, particularly in astronomy, navigation and surveying. So they began breaking their calculations down into tiny basic math problems and hiring gangs of people ➔

MAYBE CALLING THEM PLAINS WAS A POOR CHOICE OF WORDS.

Many people think of Nebraska as flat, featureless and unappealing, probably due to its location in the heart of the Great Plains. Perhaps we should have called them the Great Dazzling Spectacles or something, because to us, the Plains are anything but plain. They're majestic, beautiful and awe-inspiring in their own way. Not everyone can appreciate that. But if you can, go to **VisitNebraska.com** for your free Travel Guide. And prepare to be greatly dazzled.

Nebraska
HONESTLY, IT'S NOT FOR EVERYONE.

to solve them. The work wasn't always hard, though it required precision and an ability to work for long hours. Mostly, the computers were young men.

But by the late 19th century, some scientists realized that hiring women could reduce the cost of computation. The growth of education and middle-class prosperity had produced a generation of young women trained in math. So when the Harvard Observatory decided to process years of astronomic data it had gathered using its telescope, it assembled one all-female team of computers. They could be paid as little as less than half of what men got, notes David Alan Grier, author of *When Computers Were Human*.

"By supply and demand and all the other nasty things, they can hire them more cheaply than men," Grier says. "And the chief observer brags about it!"

During World War I, the Army hired a small group of women to calculate artillery trajectories. In the 1930s, the Works Progress Administration began hir-

ing its own human calculators to support engineers. Women were welcome as computers partly because the work was viewed as a dull, low-status activity. Men with elite educations generally wanted no part in it. Not only were women hired, but so were blacks, polio survivors, Jews and others who were routinely iced out of job opportunities, Grier points out.

"The reason that these pre-electronic computation jobs were feminized is they were seen as rote and de-skilled," says Mar Hicks, a historian and author of *Programmed Inequality*. It wasn't true, though: "In a lot of cases, the women doing these computation jobs actually had to have pretty advanced math skills and math training, especially if they were doing very complex calculations."

The work could require superhuman endurance, though. "They had to keep working eight hours a day doing the same equation over and over again—it must have been mind-numbing,"

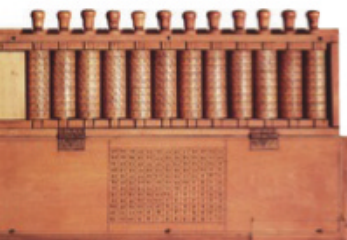
CONTINUED ON PAGE 82

Number Crunchers

A BRIEF HISTORY OF
CALCULATORS, FROM PEBBLES
IN THE SAND TO ALEXA

1617: NAPIER'S BONES

Frequently made of ivory, these number-etched rods were created by John Napier, a Scottish mathematician. By arranging the rods side by side, one could multiply and divide large numbers. Isaac Newton often used a set in his calculations.



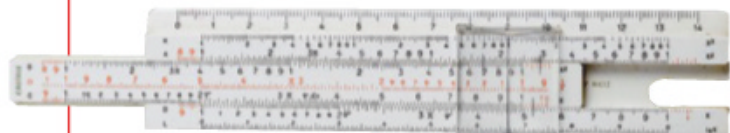
C. 1560: SECTOR

Credited to several inventors, including Galileo, the sector, or "military compass," solved geometry and trigonometry problems, such as predicting the trajectory of a cannonball.



1632: SLIDE RULE

Anglican minister William Oughtred introduced the first convenient tool to calculate logarithms. With a few improvements, the slide rule became an indispensable tool well into the 20th century.



2011: DIGITAL ASSISTANT

Since the introduction of Apple's Siri and her cousins, including Alexa (on Amazon's Echo, right), all you need is your voice to solve complicated math problems. A recent study of smart speakers found that young adults ask the devices math questions two to three times a week.



1820: ARITHMOMETER

The first mass-produced mechanical calculating device, the arithmometer, patented by Charles Xavier Thomas in France, used levers and stepped drums to turn numeral wheels, producing the answers to basic math problems.



1886: PRINTING ADDING MACHINE

A full numerical keyboard and a mechanism for printing receipts made William Seward Burroughs' invention popular not with mathematicians, but with business owners and accountants.

1970: HAND-HELD ELECTRONIC CALCULATOR

The first electronic calculator, which debuted in the 1960s, was the size of a typewriter. Within a few years, the machines had shrunk considerably; the first hand-helds, still capable of only basic functions, cost about \$400.



C. 1200: ABACUS

The first abacus was created centuries earlier, but the Chinese developed the divided counting frame we know today. The Chinese version shown here can handle calculations up to one billion.

C. 1400: KHIPU

These cords, often made of cotton, were used throughout the Incan Empire. Data such as census figures were encoded in the type, number and location of the knots. (Some believe that khipus were also used to communicate other, nonnumerical information.)



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Roaring Back

In a new exhibit about “deep time” at the National Museum of Natural History, *T. Rex* is still the chomper

N

EARLY NINE MILLION or so plant and animal species inhabit our planet, about 1.8 million cataloged under the binomial system devised by the 18th-century Swedish biologist Carl Linnaeus.

Their Latin and Greek names have had plenty of time to lodge in our collective consciousness, but most have never taken hold. *Felis catus* remains a house cat, *Drosophila melanogaster* a fruit fly. We humans often can't even accurately cite our own species—*Homo sapiens*, with the final “s.”

By
Paige Williams

Photograph by
Richard Barnes

WHEN ASKED WHY
T. REX CAPTIVATES
US, PEOPLE REPLY,
“IT WAS A REAL-LIFE
MONSTER.”

The one exception, whose scientific handle everyone gets right, is *Tyrannosaurus rex*, a marauding theropod that's been dead for over 65 million years. *Tyrannosaurus* is a mashup of the Greek words for “tyrant” and “lizard”; *rex*, in Latin, means “king.” Larger and potentially more fearsome life-forms have existed, but the “tyrant lizard king” manages to dazzle us like no other. Why?

I tried to answer this question when reporting and writing my recent book, *The Dinosaur Artist*, a true story about international fossil smuggling and the scientific consequences of the bone trade. At the

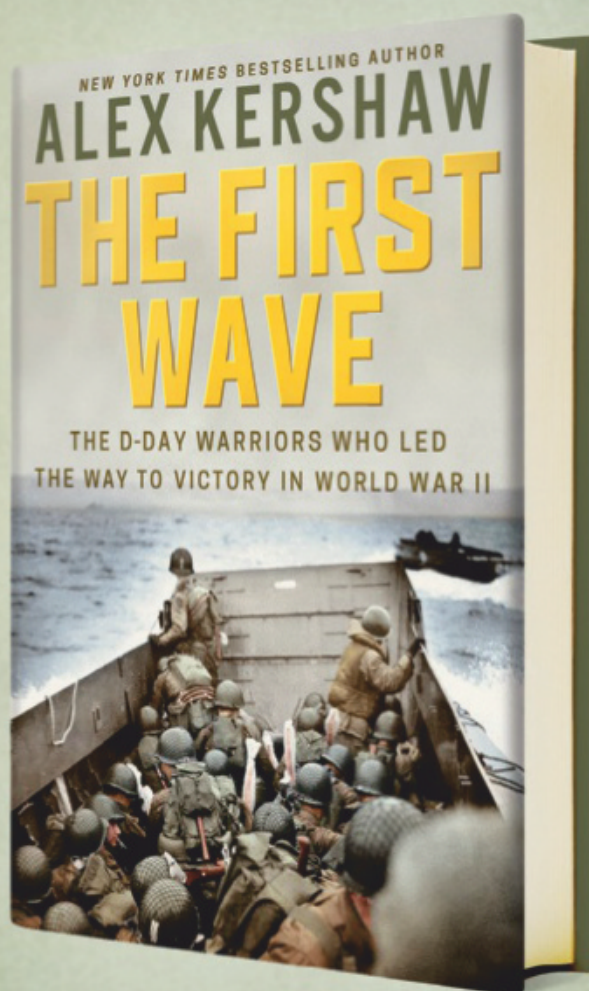
T. rex moves in for the kill on a doomed *Triceratops*—an herbivore that existed mainly on a diet of palm fronds.

center of that account was a specimen from the Gobi Desert of Mongolia: a *Tarbosaurus bataar*, the Asian cousin of *T. rex*. They were so similar, they could've been twins. Whenever I asked people why they're so captivated by *rex* and its kind, they usually replied with some version of “It was a real-life monster.”

Tyrannosaurus rex stood some 40 feet long and at least 12 feet tall, and weighed up to 15,500 pounds. It would have looked almost puny, however, next to a plant-eating behemoth like 105-foot-long *Diplodocus*. The awe surrounding *T. rex* owes to the apex predator's imagined ferocity. Its serrated teeth are

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prologue

continually compared to bananas in size. Its head was as large as a bathtub. Its curved claws would have shredded other animals.

FOSSILS ARE PORTALS to what geologists and paleontologists call “deep time.” To hold a *Tyrannosaurus* tooth in the palm of your hand, or to encounter a skeleton up close, is to come into contact with tangible evidence of earth’s distant past.

That immediate connection with prehistory is on display in dramatic fashion at the Smithsonian National Museum of Natural History’s new 31,000-square-foot fossil hall. Holding pride of place is the reinstalled, 15-foot-tall *T. rex* skeleton, on long-term loan from the U.S. Army Corps of Engineers.

T. rex lived during the Cretaceous, the geological period that ended when an asteroid strike wiped out the terrestrial dinosaurs. The first partial skeleton was discovered in 1902 by legendary fossil hunter Barnum Brown, a native Kansan. Brown found the remains in the Hell Creek Formation, a rich bone bed that runs through eastern Montana and into South Dakota.

By 1988, only nine mostly complete *T. rex* skeletons had been located, anywhere. Seven had come from Montana. On Labor Day weekend that year, rancher Kathy Wankel, who enjoyed bone-hunting in the Hell Creek with her family, spotted a fossil embedded in the dirt near Montana’s Fort Peck Reservoir. She and her husband, Tom, tried prying it out of the earth, which had baked hard, like concrete, during the dry summer.

The Wankels were able to extract part of a shoulder blade and arm. They took the fossils to the Museum of the Rockies, in Bozeman, where the paleontologist Jack Horner recognized them as correlating to *Tyrannosaurus rex*. The museum dug out the skeleton, discovering it to be 85 percent intact—a remarkable percentage. Not only that—Wankel had unearthed

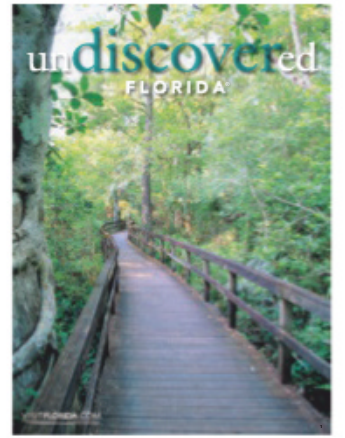
“
**ITS TEETH ARE COMPARED TO THE SIZE
OF BANANAS. ITS HEAD WAS AS LARGE AS
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HAVE SHREDDED OTHER ANIMALS.**
”

a specimen that contained the first complete *T. rex* forelimb known to science. Because the interior of *rex* bones can be read like tree rings, paleontologists determined that this particular dinosaur was about 18 when it died, ten years short of the species’ estimated life span.

The “Wankel *T. rex*” at first was displayed in Bozeman. (The federal government owns it because the bones came from lands controlled by the Army Corps of Engineers.) In 2013, the Smithsonian arranged for the skeleton to be displayed for the next 50 years in the National Museum of Natural History, as the centerpiece of its soaring new fossil hall.

Forty feet long, the skeleton is shown ripping the head off a hapless *Triceratops*. Its new name: “The Nation’s *T. rex*.” ♦

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MY, WHAT BIG TEETH YOU HAVE!

Reimagining the megalodon, the world's most terrifying sea creature

WHEN I REACHED the world's pre-eminent sculptor of long-dead monsters, he was standing atop a ladder inside a 16-foot-tall section of a megalodon tail that was propped upright in his warehouse-size studio. "I'm sorry if it sounds like I'm inside a bathroom," Gary Staab said on his cellphone. The tail was part of a 52-foot-long, life-size model of the prehistoric shark that Staab was custom-building for the Smithsonian's National Museum of Natural History.

The mighty megalodon, terror of the ancient oceans, could grow to 60 feet long, with a mouth stretching more than 9 feet wide and a bite-force stronger than any other creature ever, living or dead. The violent damage it caused to its prey, and the rows of serrated teeth, have given the shark the reputation of an enormous prehistoric Jaws—"a great white on steroids," says Hans Sues, chair of paleobiology at the museum.

In fact, Sues says, evidence suggests that megalodons, which lived between 23 million and 3.6 million years ago, were more closely related to modern mako sharks than to great whites, giving them more slender bodies than great whites and a bronzy back befitting a predator that preferred coastal waters.

Plentiful megalodon teeth (and a number of calcified vertebrae) have been found in ancient seafloors

that are now exposed—in the cliffs along the Chesapeake Bay, for example. Those fossils were all Staab was going to get: Like modern sharks, the megalodon's skeleton was made from cartilage, which decomposes. So to design the model, he and his museum collaborators used a formula that extrapolates from tooth length and the body geometry of modern relatives, and found that his shark would be 24 feet across the front fins. "That's the size of a Cessna," he told me.

To bring the shark to life, Staab then hand-sculpted a detailed, six-foot-long clay model, laser-scanned the sculpture and milled 386 foam pieces that, when assembled, became a full-scale prototype (the foam itself being too flammable for museum display). Next he fabricated 21 fiberglass panels on top of that, with interior ribs that aligned and bolted together.

In April, the model was broken down and trucked from Staab's studio in Kearney, Missouri, to Washington, D.C. On the museum floor, Staab reassembled the behemoth from the inside before crawling out a section in the tail. The shark was touched up with epoxy and fresh paint and raised 85 feet in the air to hang, menacingly, above museum visitors dining in a new café.

"My job is to not have a style," he said, "but rather to be the animal—to make that thing as believable as possible." ♦

▲ Artist Gary Staab assembles the massive megalodon. A scale model at bottom right shows what the finished creature will look like.

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INSIDE

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AMERICA'S

ON THE MOON AT THE SAME TIME, A NEW **BEHIND-THE-SCENES** VIEW OF

GREATEST

APOLLO 11'S UNLIKELY TRIUMPH 50 YEARS AGO | **BY CHARLES FISHMAN**

ADVENTURE



PHOTOGRAPH BY **CADE MARTIN**

Armstrong's helmet visors
were designed to protect
against hazards, from
micrometeoroids to
infrared light.

The Moon has a smell. It has no air, but it has a smell. Each pair of Apollo astronauts to land on the Moon tramped lots of Moon dust back into the lunar module—it was deep gray, fine-grained and extremely clingy—and when they unsnapped their helmets, Neil Armstrong said, “We were aware of a new scent in the air of the cabin that clearly came from all the lunar material that had accumulated on and in our clothes.” To him, it was “the scent of wet ashes.” To his Apollo 11 crewmate Buzz Aldrin, it was “the smell in the air after a firecracker has gone off.”

The Moon surface revealed dead volcanoes and lava flows, pocked by asteroid or meteorite impacts (pictured here: view from outside the lunar module, in a colorized, superimposed image).



Armstrong collected this fragment of fine-grained basalt. Lunar rocks were stored onboard in stainless steel vacuum containers.

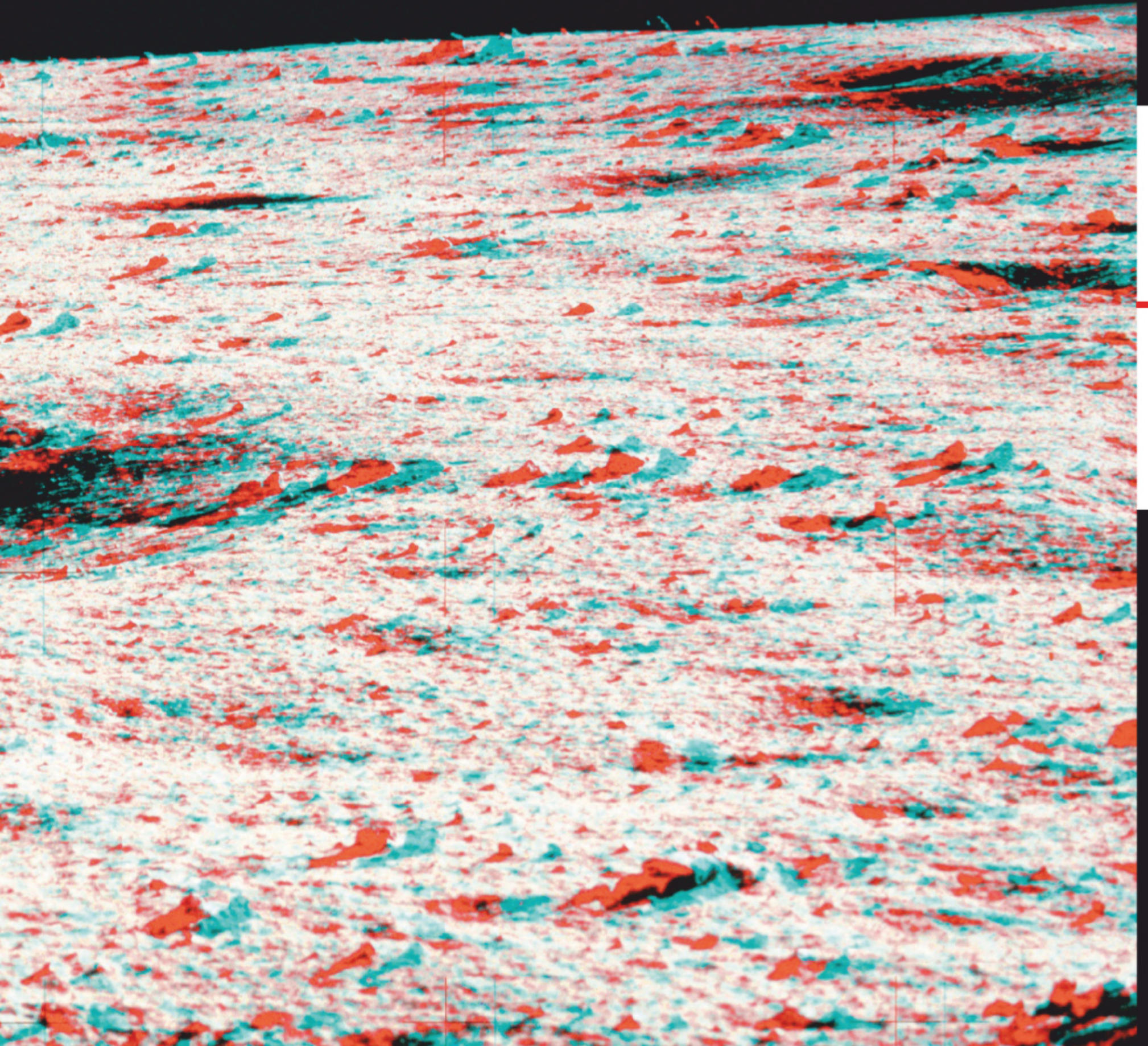


All the astronauts who walked on the Moon noticed it, and many commented on it to Mission Control. Harrison Schmitt, the geologist who flew on Apollo 17, the last lunar landing, said after his second Moonwalk, “Smells like someone’s been firing a carbine in here.” Almost unaccountably, no one had warned lunar module pilot Jim Irwin about the dust. When he took off his helmet inside the cramped lunar module cabin, he said, “There’s a funny smell in here.” His Apollo 15 crewmate Dave Scott said: “Yeah, I think that’s the lunar dirt smell. Never smelled lunar dirt before, but we got most of it right here with us.”

Moon dust was a mystery that the National Aeronautics and Space Administration had, in fact, thought about. Cornell Uni-

versity astrophysicist Thomas Gold warned NASA that the dust had been isolated from oxygen for so long that it might well be highly chemically reactive. If too much dust was carried inside the lunar module’s cabin, the moment the astronauts repressurized it with air and the dust came into contact with oxygen, it might start burning, or even cause an explosion. (Gold, who correctly predicted early on that the Moon’s surface would be covered with powdery dust, also had warned NASA that the dust might be so deep that the lunar module and the astronauts themselves could sink irretrievably into it.)

Among the thousands of things they were keeping in mind while flying to the Moon, Armstrong and Aldrin had been



briefed about the very small possibility that the lunar dust could ignite. “A late-July fireworks display on the Moon was not something advisable,” said Aldrin.

Armstrong and Aldrin did their own test. Just a moment after he became the first human being to step onto the Moon, Armstrong had scooped a bit of lunar dirt into a sample bag and put it in a pocket of his spacesuit—a contingency sample, in the event the astronauts had to leave suddenly without collecting rocks. Back inside the lunar module the duo opened the bag and spread the lunar soil on top of the ascent engine. As they repressurized the cabin, they watched to see if the dirt started to smolder. “If it did, we’d stop pressurization, open the hatch and toss it out,” Aldrin explained. “But nothing happened.”

The Moon dust turned out to be so clingy and so irritating that on the one night that Armstrong and Aldrin spent in the lunar module on the surface of the Moon, they slept in their helmets and gloves, in part to avoid breathing the dust floating around inside the cabin.

By the time the Moon rocks and dust got back to Earth—a total of 842 pounds from six lunar landings—the odor was gone from the samples, exposed to air and moisture in their storage boxes. No one has quite figured out what caused the odor to begin with, or why it was so like spent gunpowder, which is chemically nothing like Moon rock. “Very distinctive smell,” Apollo 12 commander Pete Conrad said. “I’ll never forget. And I’ve never smelled it again since then.”

IN 1999, as the century was ending, the historian Arthur Schlesinger Jr. was among a group of people who was asked to name the most significant human achievement of the 20th century. In ranking the events, Schlesinger said, “I put DNA and penicillin and the computer and the microchip in the first ten because they’ve transformed civilization.” But in 500 years, if the United States of America still exists, most of its history will have faded to invisibility. “Pearl Harbor will be as remote as the War of the Roses,” said Schlesinger. “The one thing for which this century will be remembered 500 years from now was: This was the century when we began the exploration of space.” He picked the first Moon landing, Apollo 11, as the most significant event of the 20th century.

The trip from one small planet to its smaller nearby moon might someday seem as routine to us as a commercial flight today from Dallas to New York City. But it is hard to argue with Schlesinger’s larger observation: In the chronicle

of humanity, the first missions by people from Earth through space to another planetary body are unlikely ever to be lost to history, to memory, or to storytelling.

The leap to the Moon in the 1960s was an astonishing accomplishment. But why? What made it astonishing? We’ve lost track not just of the details; we’ve lost track of the plot itself. What exactly was the hard part?

The answer is simple: When President John F. Kennedy declared in 1961 that the United States would go to the Moon, he was committing the nation to do something we simply couldn’t do. We didn’t have the tools or equipment—the rockets or the launchpads, the spacesuits or the computers or the micro-gravity food. And it isn’t just that we didn’t have what we would need; we didn’t even know what we would need. We didn’t have a list; no one in the world had a list. Indeed, our unpreparedness for the task goes a level deeper: We didn’t even know how to fly to the Moon. We didn’t know what course to fly to get there from here. And as the small example of lunar dirt shows, we didn’t know what we would find when we got there. Physicians worried that people wouldn’t be able to think in micro-gravity conditions. Mathematicians worried that we wouldn’t be able to calculate how to rendezvous two spacecraft in orbit—to bring them together in space and dock them in flight both perfectly and safely.

On May 25, 1961, when Kennedy asked Congress to send Americans to the Moon before the 1960s were over, NASA had no rockets to launch astronauts to the Moon, no computer portable enough to guide a spaceship to the Moon,

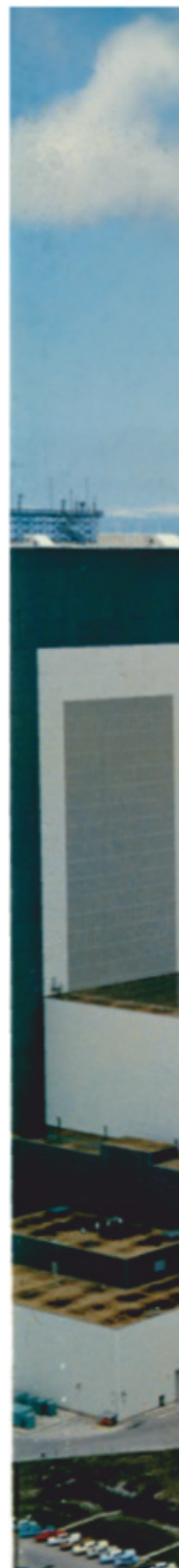
no spacesuits to wear on the way, no spaceship to land astronauts on the surface (let alone a Moon car to let them drive around and explore), no network of tracking stations to talk to the astronauts en route.

“When [Kennedy] asked us to do that in 1961, it was impossible,” said Chris Kraft, the man who invented Mission Control. “We made it possible. We, the United States, made it possible.”

Ten thousand problems had to be solved to get us to the Moon. Every one of those challenges was tackled and mastered between May 1961 and July 1969. The astronauts, the nation, flew to the Moon because hundreds of thousands of scientists, engineers, managers and factory workers unraveled a series of puzzles, often without knowing whether the puzzle had a good solution.

In retrospect, the results are both bold and bemusing. The Apollo spacecraft ended up with what was, for its time, the smallest, fastest and most nimble computer in a single package anywhere in

AMERICANS
CONSTANTLY
QUESTIONED
WHY WE
WERE GOING
TO THE MOON
WHEN WE
COULDN'T
HANDLE OUR
PROBLEMS
ON EARTH.





▲
An aerial view of Cape Kennedy, May 20, 1969, shows the Saturn V rocket as it was transported down the 3.5-mile approach to Launch Complex 39A.

the world. That computer navigated through space and helped the astronauts operate the ship. But the astronauts also traveled to the Moon with paper star charts so they could use a sextant to take star sightings—like 18th-century explorers on the deck of a ship—and cross-check their computer's navigation. The software of the computer was stitched together by women sitting at specialized looms—using wire instead of thread. In fact, an arresting amount of work across Apollo was done by hand: The heat shield was applied to the spaceship by hand with a fancy caulking gun; the parachutes were sewn by hand, and then folded by hand. The only three staff members in the country who were trained and licensed to fold and pack the Apollo parachutes were considered so indispensable that NASA officials forbade them to ever ride in the same car, to avoid

their all being injured in a single accident. Despite its high-tech aura, we have lost sight of the extent to which the lunar mission was handmade.

The race to the Moon in the 1960s was, in fact, a real race, motivated by the Cold War and sustained by politics. It has been only 50 years—not 500—and yet that part of the story too has faded.

One of the ribbons of magic running through the Apollo missions is that an all-out effort born from bitter rivalry ended up uniting the world in awe and joy and appreciation in a way it had never been united before and has never been united since.

The mission to land astronauts on the Moon is all the more compelling because it was part of a decade of transformation, tragedy and division in the United States. The nation's lunar ambition, we tend to forget, was itself divisive. On the eve of the launch

of Apollo 11, civil rights protesters, led by the Rev. Ralph Abernathy, marched on Cape Kennedy.

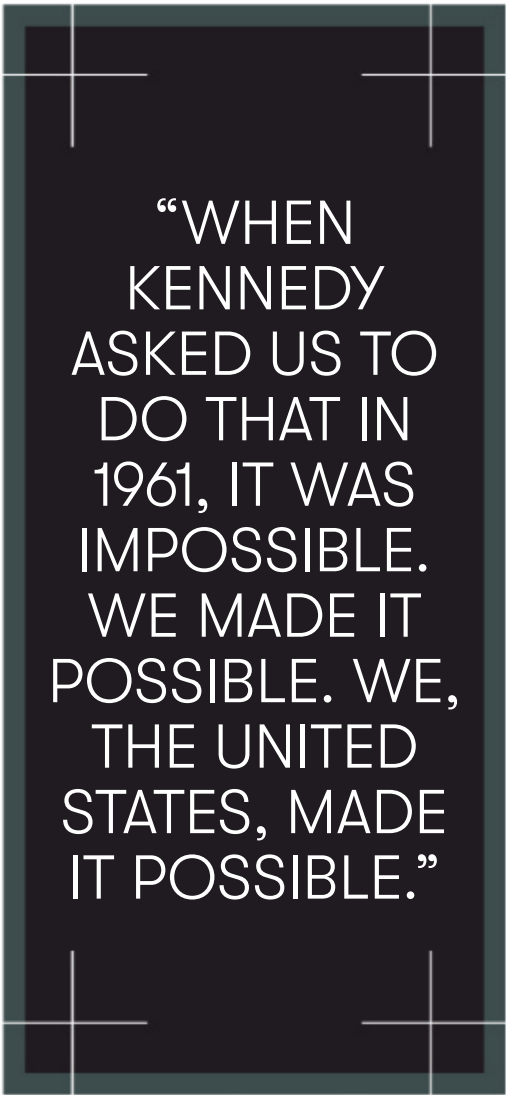
In that way, the story of Apollo holds echoes and lessons for our own era. A nation determined to accomplish something big and worthwhile can do it, even when the goal seems beyond reach, even when the nation is divided. Kennedy said of the Apollo mission that it was hard—we were going to the Moon precisely because doing so was hard—and that it would “serve to organize and measure the best of our energies and skills.” And measure the breadth of our spirit as well.

TODAY THE MOON landing has ascended to the realm of American mythology. In our imaginations, it’s a snippet of crackly audio, a calm and slightly hesitant Neil Armstrong stepping from the ladder onto the surface of the Moon, saying, “That’s one small step for man, one giant leap for mankind.” It is such a landmark accomplishment that the decade-long journey has been concentrated into a single event, as if on a summer day in 1969, three men climbed into a rocket, flew to the Moon, pulled on their spacesuits, took a few steps, planted the American flag, and then came home.

But the magic, of course, was the result of an incredible effort—an effort unlike any that had been seen before. Three times as many people worked on Apollo as on the Manhattan Project to create the atomic bomb. In 1961, the year Kennedy formally announced Apollo, NASA spent \$1 million on the program for the year. Five years later NASA was spending about \$1 million every three hours on Apollo, 24 hours a day.

One myth holds that Americans enthusiastically supported NASA and the space program, that Americans wanted to go to the Moon. In fact two American presidents in a row hauled the space program all the way to the Moon with not even half of Americans saying they thought it was worthwhile. The ’60s were tumultuous, riven by the Vietnam War, urban riots, the assassinations. Americans constantly questioned why we were going to the Moon when we couldn’t handle our problems on Earth.

As early as 1964, when asked if America should “go all out to beat the Russians in a manned flight to the Moon,” only 26 percent of Americans said yes. During Christmas 1968, NASA sent three astronauts in an Apollo capsule all the way to the Moon, where they orbited just 70 miles over the surface, and on Christmas Eve, in a live, prime-time TV broadcast, they shared pictures of the Moon’s surface, as seen out their windows. Then the three astronauts, Bill Anders, Jim Lovell and Frank Borman, read aloud the first ten verses of Genesis to what was then the largest TV audience in history. From orbit, Anders took one of the



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most famous pictures of all time, the photo of the Earth floating in space above the Moon, the first full-color photo of Earth from space, later titled *Earthrise*, a single image credited with helping inspire the modern environmental movement.

ANTICIPATION for the actual Moon landing should have been extraordinary. In fact, as earlier in the decade, and despite years of saturation coverage of Apollo and the astronauts, it was anything but universal. Four weeks after Apollo 8’s telecast from lunar orbit, the Harris Poll conducted a survey and asked Americans if they favored landing a man on the Moon. Only 39 percent said yes. Asked if they thought the space program was worth the \$4 billion a year it was costing, 55 percent of Americans said no. That year, 1968, the war in Vietnam had cost \$19.3 billion, more than the total cost of Apollo to that point, and had taken the lives of 16,899 U.S. troops—almost 50 dead every single day—by far the worst single year of the war for the U.S. military. Americans would prove to be delighted to have flown to the Moon, but they were not preoccupied by it.

The big myth of Apollo is that it was somehow a failure, or at least a disappointment. That’s certainly the conventional wisdom—that while the landings were a triumph, the aimless U.S. space program since then means Apollo itself was also pointless. Where is the Mars landing? Where are the Moon bases, the network of orbital outposts? We haven’t done any of that, and we’re decades from doing it now. That misunderstands Apollo, though. The success is the very age we live in now. The race to the Moon didn’t usher in the space age; it ushered in the digital age.

Historians of Silicon Valley and its origins may skip briskly past Apollo and NASA, which seem to have operated in a parallel world without much connection to or impact on the wizards of Intel and Microsoft. But the space program in the 1960s did two things to lay the foundation of the digital revolution. First, NASA used integrated circuits—the first computer chips—in the computers that flew the Apollo command module and the Apollo lunar module. Except for the U.S. Air Force, NASA was the first significant customer for integrated circuits. Microchips power the world now, of course, but in 1962 they were little more than three years old, and for Apollo they were a brilliant if controversial bet. Even IBM decided against using them in the company’s computers in the early 1960s. NASA’s demand for integrated circuits, and its insistence on their near-flawless manufacture, helped create the world market for the chips and helped cut the price by 90 percent in five years.

NASA was the first organization of any kind—company or government agency—anywhere in the world to give comput-



er chips responsibility for human life. If the chips could be depended on to fly astronauts safely to the Moon, they were probably good enough for computers that would run chemical plants or analyze advertising data.

NASA also introduced Americans, and the world, to the culture and power of technology—we watched on TV for a decade as staff members at Mission Control used computers to fly spaceships to the Moon. Part of that was NASA introducing the rest of the world to “real-time computing,” a phrase that seems redundant to anyone who’s been using a computer since the late 1970s. But in 1961, there was almost no computing in which an ordinary person—an engineer, a scientist, a mathematician—sat at a machine, asked it to do calculations and got the answers while sitting there. Instead you submitted your programs on stacks of punch cards, and you got back piles of printouts based on the computer’s run of your cards—and you got those printouts hours or days later.

But the Apollo spacecraft—command module and lunar module—were flying to the Moon at almost 24,000 miles per hour. That’s six miles every second. The astronauts couldn’t wait a minute for their calculations; in fact, if they wanted to arrive at the right spot on the Moon, they couldn’t wait a second. In an era when even the batch-processing machines took up vast rooms of floor space, the Apollo spacecraft had real-time computers that fit into a single cubic foot, a stunning feat of both engineering and programming.

Kennedy’s call to leap to the Moon ahead of the Russians was greeted with wild enthusiasm in the spring and summer of 1961. But when it came to public events, Americans’ attention spans were no longer in the 1960s than they are today. We were no more inclined toward the virtues of slow-and-steady progress, no more capable of delayed gratification. Even before 1961 was over, there were prominent public voices stoking skepticism and dissent about the value of the Moon race.

In 1961, Senator Paul H. Douglas released his own poll, not of the American people but of U.S. space scientists. The question: Was sending astronauts to the Moon, “at the earliest feasible moment,” of great scientific value? Douglas had arranged to poll the membership of the American Astronomical Society, and received 381 written replies from astronomers and space scientists. Of those, 36 percent said a manned Moon mission had “great scientific value,” and 35 percent said it had “little scientific value.” And unmanned, robotic missions to the Moon? Sixty-six percent of space scientists said they would have “great scientific value.” Douglas, a liberal Democrat, was a member of Kennedy’s own party, and he had gone to some trouble to establish that America’s actual space scientists judged that the race to the Moon wasn’t worth it. “If the astronomers are not competent [to decide],” asked Douglas, “who is?”

Norbert Wiener, a professor and legendary mathematician at MIT, dismissed Apollo in a late 1961 interview as a “moon-doggie,” a word the press and NASA critics loved; through the end of 1961 and into 1962, “moondoggie” started to pop up regularly in coverage of the space program, particularly in stories about spending and in editorials.

In January 1962 the *New York Times* published an editorial pointing out that “the grand total for the Moon excursion would reproduce from 75 to 120 universities about the size of Harvard, with some [money] left over”—a Moon landing, or a Harvard University for every state?

In August 1962 the Russians launched two cosmonauts, in separate spaceships, within 24 hours of each other, the double mission totaling seven days in space at a moment when the total for all four American spaceflights was 11 hours. Kennedy was asked at a press conference why Americans shouldn’t be pessimistic since they were not just second to the Soviets but “now a poor second.” “We are behind and we are going to be behind for a while,” he replied. “But I believe that before the end of this decade is out, the United States will be ahead....This year we submitted a space budget which was greater than the combined eight space budgets of the previous eight years.” The press conference comments were defensive and reflexive. There was no eloquence about space in them, the responses more dutiful than enthusiastic.

IN THE FALL OF 1962, Kennedy did a two-day tour of space facilities to see for himself how the Moon

program was taking shape. Huntsville, Alabama, home to Wernher von Braun’s rocket team, was the first stop. Von Braun showed the president a model of the Saturn rocket that would eventually launch astronauts to the Moon. “This is the vehicle which is designed to fulfill your promise to put a man on the Moon by the end of the decade,” von Braun told Kennedy. He paused, then added, “By God, we’ll do it!”

Von Braun took Kennedy to the firing of a Saturn C-1 rocket as a demonstration of the coming power of American rocketry. The test—eight engines firing simultaneously, roaring red-orange rocket thrust out of a test stand, with Kennedy, von Braun and the visiting party in a viewing bunker less than a

half-mile away—shook the ground and sent shock waves across the Alabama test facility. When the engines stilled, Kennedy turned with a wide grin to von Braun and grabbed his hand in congratulations. The president was apparently so captivated by von Braun’s running commentary that he took the rocket scientist—the biggest U.S. space personality outside the astronauts themselves—on the plane with him to Cape Canaveral.

At the cape, JFK visited four launchpads, including one where he got a guided tour from astronaut Wally Schirra of the Atlas rocket and Mercury capsule Schirra was set to ride into orbit in about two weeks.



At the Rice University Stadium on September 12, 1962, President Kennedy vowed that the U.S. would reach the Moon “first before this decade is out.”



Kennedy ended the day in Houston, where his popularity was on vivid display. The city's police chief said 200,000 people—more than one in every five residents of Houston at the time—had come out to see the president, who rode in an open car from the airport to his hotel. Kennedy spent part of the next day at NASA's temporary Houston facilities—the space center itself was under construction—including seeing a very early mock-up of the lunar module, then called “the bug.” But the emotional and political climax of Kennedy's tour came Wednesday morning at the Rice University football stadium. In the blazing early-morning Texas heat—already 89 degree at 10 a.m., with Kennedy and his party wearing dress shirts, coats and ties—the president gave a speech designed to lift the space program up out of the political squabbles and budget bickering that was starting to beset it. “The United States was not built by those who waited and rested,” he said. “This country was conquered by those who moved forward—and so will space.”

SPACE DIDN'T JUST create the opportunity for knowledge and adventure, for American destiny and American values. It created an obligation to reach for the Moon, and to reach beyond.

That is the point of the most famous passage of the Rice University speech: “We choose to go to the Moon. We choose to go to the Moon. . . . We choose to go to the Moon, in this decade, and do the other things, not because they are easy, but because they are hard, because that goal will serve to organize and measure the best of our energies and skills, because that challenge is one that we are willing to accept, one we are unwilling to postpone, and one which we intend to win, and the others, too.”

The Rice speech took place on September 12, 1962. Ten weeks later, on November 21, in the cabinet room, Kennedy presided over a meeting about America's space program with a very different tone. It was fractious and frustrating, driven by the president's own impatience. He didn't like the slow pace of the program; he didn't like what it was costing; and he didn't like the answers he was getting from the people gathered around the table with him, including James Webb, the NASA administrator, and his most senior lieutenants.

Ostensibly the occasion for the meeting was to hash out whether NASA and Kennedy were going to push Congress for an extra \$400 million for Apollo before the next budget cycle. Not even the NASA people agreed about the wisdom of that.

The poetry of the Rice speech, the vision of the future it expressed, is nowhere to be found in the cabinet room that Wednesday. We know this because, although the meeting was private, Kennedy had a secret taping system installed in the White House, as FDR had, as LBJ would, as Nixon, most famously, would.

The recordings preserve two high-level conversations about space that reveal a very different Kennedy attitude about the race to the Moon. At the first, just ten weeks after his Rice University speech, Kennedy spent 30 minutes asking questions about NASA's budget and spending, trying to get to the bottom of the schedule. “Gemini has slipped how much?” he asked.

To much laughter—there were nine people in the meeting besides the president, four of them space agency people all too familiar with countdowns and launches that frequently

slipped—Webb responded, “This word ‘slip’ is the wrong word.” To which Kennedy says, “I'm sorry, I'll pick another word.”

Webb had been telling Kennedy that a Moon landing was possible in late 1967, but was more likely in 1968. Kennedy wanted it sooner. How do you move it back into 1967? Would the \$400 million they were there to discuss do that? How about *early* 1967? What would that take? Kennedy seemed puzzled that more money wouldn't necessarily make it happen sooner.

There is a long exchange in which Kennedy tries to understand why getting \$400 million extra right now would help Gemini but wasn't likely to move Apollo any sooner. He didn't understand the details of staged technology development, that you have to build and fly Gemini in part to help you make the right decisions about Apollo. Four months here or there over four years is hard to nail down.

Thirty minutes into the conversation, the president takes a step back. “Do you think this program is the top-priority program of the agency?” Kennedy asked Webb.

“No sir, I do not,” Webb answered without hesitation. “I think it is one of the top priority programs, but I think it's very important to recognize here—” Webb started to explain the importance of some of NASA's non-Moon programs. Kennedy lowered his voice and simply stepped into Webb's conversational stream.

“Jim, I think it is the top priority. I think we ought to have that very clear. This is, whether we like it or not, in a sense a race. If we get second to the Moon, it's nice, but it's like being second any time. So that if we're second by six months, because we didn't give it the kind of priority—then of course that would be very serious.”

The president was being as clear as he possibly could. It was fine to fly to the Moon, but the point of such urgency—the tripling of NASA's budget in just two years—was to reach the Moon before the Russians. It didn't seem clear to the people in the White House cabinet room that day, but the only reason they were there at all was that Kennedy needed to beat the Russians. Not because he needed to fly to the Moon.

“Otherwise, we shouldn't be spending this kind of money, because I'm not that interested in space.”

THE CONVERSATION CONTINUED well after Kennedy lost patience, and left. But no one took up, or even commented on, those arresting words, which must have been quite stunning to the space people in the room: I'm not that interested in space. The man who launched the United States to the Moon, “the greatest adventure on which man has ever embarked,” as he called it at Rice, just wanted to get there before the Russians.

In 1963 the politics of going to the Moon got even more challenging than they were in 1962. Webb was worried about the scientific community, many of whom felt that a space program that sent humans into space would consume huge amounts of federal money that could be used for scientific research with more immediate value on Earth.

In April, in an editorial in the prestigious journal *Science*, the editor, Philip Abelson, provided precisely the cerebral, almost disdainful critique Webb had been hearing in his conversations with scientists. Abelson walked through the justifications—military value, technological innovation, scientific discovery and the propaganda value of beating the Russians—

APOLLO AT 50

New tributes to the ultimate space epic blast off this summer at the Smithsonian's National Air and Space Museum

"50 Years From Tranquility Base"

ONGOING

The museum exhibition includes Neil Armstrong's Omega chronograph, on view for the first time in 20 years. The 16-mm Data Acquisition movie camera, used to record Armstrong's first steps on the Moon from the lunar module window, is on display for the first time with the film magazine used to capture the moment.

Apollo at the Park

JUNE THROUGH FALL 2019

The museum will place 15 statues of Neil Armstrong's spacesuit—created by 3-D scan data—in Major League Baseball stadiums across the country.

Apollo 11 Anniversary Celebration

JULY 16-20, 2019

Armstrong's newly conserved spacesuit (below) will go on display for the first time in 13 years. On July 20, the museum will hold festivities day and night. Lectures on Apollo and lunar exploration continue throughout 2019.

Learn more about these and other events at Smithsonian.com/Apollo11.



and dismissed each in turn. "Military applications seem remote," he wrote. The technological innovations "have not been impressive." If actual science was a goal—and no scientist was on any imagined Moon landing crew yet—"most of the interesting questions about the Moon can be studied by electronic devices," at about 1 percent of the cost of using astronauts.

As for the worldwide prestige, "the lasting propaganda value of placing a man on the Moon has been vastly overestimated. The first lunar landing will be a great occasion; subsequent boredom is inevitable."

On June 10, Abelson was among a group of ten scientists called to testify, over two days, before the Senate Committee on Aeronautical and Space Sciences about the future of Apollo. Abelson, a physicist and a key contributor to the creation of the atomic bomb, told the senators, "[The] diversion of talent to the space program is having and will have direct and indirect damaging effects on almost every area of science, technology and medicine. I believe that [Apollo] may delay the conquest of cancer and mental illness. I don't see anything magical about this decade. The Moon has been there a long time, and will continue to be there a long time."

Two days later, former president Dwight Eisenhower spoke to a breakfast gathering of Republican members of Congress in Washington, where he was sharply critical of Kennedy's spending plans overall. Asked about the space budget, Eisenhower replied, "Anybody who would spend \$40 billion in a

race to the Moon for national prestige is nuts." The line drew sustained applause from the 160 Republican congressmen at the event. Leave aside that Eisenhower was going with the most extreme estimate of the Moon cost (one that didn't come close to true in reality, even nine years later), that was the immediate past president of the United States calling the current president of the United States crazy. Headline writers from one side of America to the other loved the story, which made the front pages of dozens of newspapers with some variation of the headline "Ike Calls Moon Race 'Nuts.'"

As it happens, on that day NASA announced the end of the Mercury program, the small capsules with just a single astronaut. Next up, the much more sophisticated, and much more ambitious, missions of Gemini. But the last Mercury flight was May 1963, and the first manned Gemini flight wouldn't come until March 1965—a long time between

"space spectacles," as Kennedy called them, to fire the public imagination, and enough time for an entire presidential and congressional election to play out without a single spaceflight.

In Congress, which was also thinking about elections coming the following year, NASA had gone from receiving near-unanimous support after Kennedy's initial "go to the Moon" speech to being viewed as an agency where money might be harvested for other purposes.

AS IF TO UNDERScore THE SHIFT

in public attitude, on September 13, 1963, the *Saturday Evening Post*, one of the widest circulation weekly magazines in the country, published a story titled "Are We Wasting Billions in Space?" On the cover the headline was just "Billions Wasted in Space," without the question mark, a crisper summary of the story's point. The Moon race, the story argued, had become a "boondoggle" and "a circus."

The second recorded meeting that reveals Kennedy's private thinking about space took place on September 18, 1963, in the Oval Office. Only President Kennedy and Jim Webb were present. On August 5, the United States, the USSR and Great Britain had signed a partial nuclear test-ban treaty, the first limits on nuclear weapons, and a major thaw in the Cold War. This meeting with Webb was long—46 minutes. The question was how to sustain Apollo during what were clearly going to be years of spending without years of excitement.

Right at the start, Kennedy said, "It's been a couple years, and . . . right now, I don't think the space program has much political excitement."

"I agree," said Webb. "I think this is a real problem."

"I mean, if the Russians do some tremendous feat, then it would stimulate interest again," continued Kennedy. "But right now, space has lost a lot of its glamour."

The immediate cuts that congressional committees had proposed to the NASA budget would slow America's leap to the Moon. Kennedy asked, "If we're cut that amount . . . we slip a year?"

"We'll slip at least a year," replied Webb.

Kennedy: "If I get re-elected, we're not going to the Moon in our period, are we?"

Webb: "No. No. You're not going."

Kennedy: "We're not going . . ."

Webb: "You'll fly by it."

Webb was saying that, during Kennedy's term, astronauts would fly around the Moon without landing, as Apollo 8 did, in fact, in December 1968, which would have been the end of the last year of Kennedy's second term.

"It's just going to take longer than that," Webb said. "This is a tough job. A real tough job."

It's hard to listen to the conversation while setting aside everything we know that would come in the next ten weeks, and the next six years, and just imagine it from Kennedy's point of view. This huge project he had set in motion. He wasn't even done with his first term. Congressional critics weren't just talking down the Moon landing; they were cutting the budget for the Moon landing. And Kennedy wouldn't just have to muster the political support for Apollo through the election in a year; he was imagining having to sustain support for it through his entire next term, to which he hadn't been re-elected yet. And even if he could do it, he wouldn't enjoy the accomplishment during his own presidency.

It would have been a keen moment of disappointment, and you can hear it in Kennedy's voice. It would also have been a moment of political calculation. How do you possibly hang on to a discretionary program of such enormous scale, already under fire, through four more budget cycles?

Just after that, Kennedy asked a version of the same question he had asked a year earlier: "Do you think the manned landing on the Moon's a good idea?"

"Yes sir," replied Webb. "I think it is."

To Kennedy, the broader politics were simple and discouraging: "We don't have anything coming up for the next 14 months. So I'm going into the campaign to defend this program, and we won't have had anything for a year and a half." He actually sounded disappointed, almost irritated by the timing of this flight gap. How could he talk with enthusiasm about space, when there were no spaceflights for anyone to be enthusiastic about?

In fact Kennedy saw only one strategy for protecting Apollo, an extension of the very first reasoning behind the Moon race. "I want to get the military shield over this thing," he said, meaning, he wanted to be able to argue that manned spaceflight had explicit national security and defense value.

Webb went deep into the budget negotiations with Kenne-

dy, talking about congressmen by name, but he also pulled back to remind the president of the incredible power of this kind of exploration and science for the life of Americans, for understanding how the world works, and also for the practical value of technology development, and for inspiring American students to pursue science and engineering. "The younger folks see this much better than my generation," Webb said, having visited high schools and colleges around the country. He was talking about all the things that made Americans nervous after Sputnik, all the things Kennedy himself so forcefully argued in his Rice University speech. The lunar landing, said Webb, is "one of the most important things that's been done in this nation." What will come from going to the Moon will be "staggering things in terms of the development of the human intellect."

The NASA chief concluded, "I predict you are not going to be sorry—ever—that you did this."

ON THURSDAY, OCTOBER 10, 1963, the House passed the slimmed down \$5.1 billion NASA budget—\$600 million less than Kennedy requested, at least \$200 million less than Webb had said was necessary to stay on track for a Moon landing within the decade. That seemed to be sending an ominous signal about the fading sense of congressional urgency and enthusiasm for reaching the Moon by the end of the decade.

So if John Kennedy had not been assassinated, would Neil Armstrong and Buzz Aldrin have stepped off the ladder of the lunar module Eagle onto the Moon on July 20, 1969?

It seems unlikely.

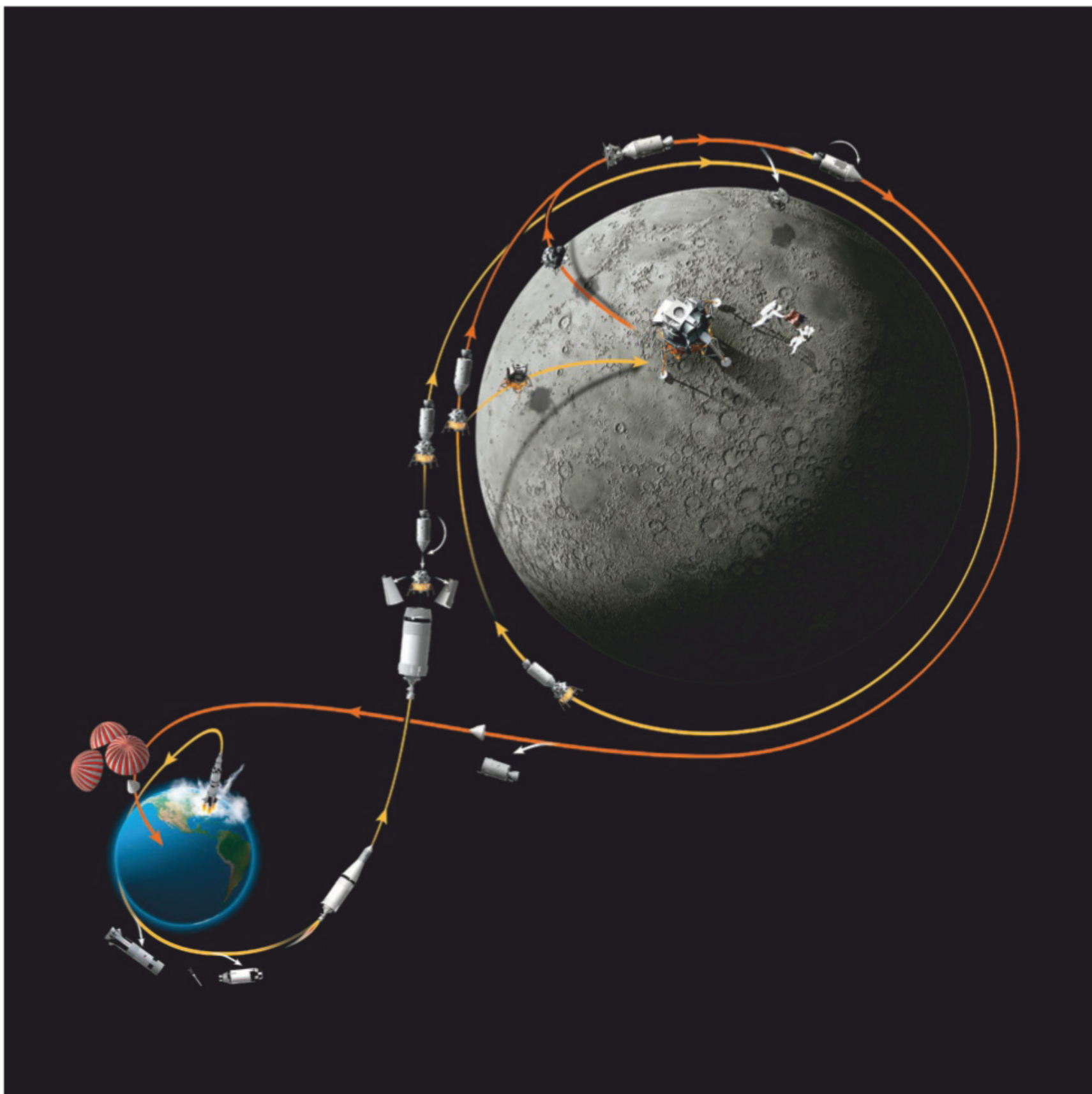
President Kennedy visited Cape Canaveral for the third time, on November 16, flying up from where he was spending the weekend in Palm Beach, for two hours of briefings and touring. He got to see the Saturn I rocket on its launchpad, the rocket that would, a month later, finally put into orbit a payload larger than anything the Russians could launch. "It will give the United States the largest booster in the world and show significant progress in space," the president said. The Saturn I was scheduled to launch in December;

it ended up being launched successfully on January 29, 1964, sending ten tons into Earth orbit in a milestone considered so significant that the midday event was carried live by the TV networks.

After a brief return to Washington, Kennedy headed to Texas the following Thursday, November 21, to make appearances in San Antonio, then Houston, followed by Fort Worth and Dallas. In San Antonio he dedicated a new Air Force research center devoted to aerospace medicine. He commented on how valuable space medical research would prove: "Medicine in space is going to make our lives healthier and happier here on



In the simulator on April 18, 1969, Aldrin (left) uses tongs to practice collecting a lunar sample while Armstrong checks the portable communications antenna.



▲
A computer-generated illustration shows the trajectory of the Apollo 11 mission and the stages of the spacecraft from launch to orbit and return.
■

Earth.” He told the audience how impressed he was with the Saturn rocket he had seen the previous Saturday. There will be “pressures in this country to do less in this area as in so many others, and temptations to do something else that is perhaps easier. But . . . the conquest of space must and will go ahead.” He didn’t mention landing on the Moon.

In the speech that had been written for him to give in Dallas at the Dallas Trade Mart—the speech he was on the way to deliver when he was shot—Kennedy would have talked with pride about reinvigorating the U.S. space program. Under his administration, the nation was spending more money on space each year than the entire space budget for the decade of the Fifties; 130 U.S. spacecraft had been put in orbit,

including invaluable and innovative weather and communications satellites, “making it clear to all that the United States of America has no intention of finishing second in space.” Space was a source of “national strength.”

Kennedy hadn’t planned to say a word that afternoon about going to the Moon.

From the evidence at hand, it’s actually hard to imagine Kennedy making the Moon landing itself a cornerstone of his second term. He had lots of other things he wanted to do.

But none of that happened, because Kennedy was killed on Friday, November 22, 1963.

Six days later President Lyndon B. Johnson announced, in his somber Thanksgiving Day address



to the nation, that he was renaming the space center in Florida the John F. Kennedy Space Center and renaming the piece of land it sat on Cape Kennedy. In a brief meeting the day before, Jacqueline Kennedy had asked Johnson to do that, and he had agreed.

Before noon on the Friday after Thanksgiving, not even 18 hours after Johnson's announcement, painters hung a sign with the new name on it over the southern security gate for Kennedy Space Center.

On January 21, 1964, President Johnson submitted to Congress his budget for the next year, proposing to cut overall federal spending from Kennedy's previous budget by \$500 million, including cuts to defense, agriculture, veterans affairs and the post office. But Johnson raised spending for NASA to \$5.3 billion, along with a request to immediately add back \$141 million for the year already under way. Whatever Kennedy's long-term space strategy had been, his death changed the political calculation, in space as in so many other arenas. Johnson, unlike Kennedy, was an authentic believer in the space program. In announcing the NASA budget, he reaffirmed his determination to get the nation to the Moon by 1970. "No matter how brilliant our scientists and engineers, how farsighted our planners and managers, or how frugal our administrators and contracting personnel, we cannot reach this goal without adequate funds," Johnson said. "There is no second-class ticket to space."

BY MARCH 1964 the most sophisticated spaceship ever conceived was well along in its design. The Apollo lunar module would carry two astronauts from lunar orbit to the Moon's surface, be their base of operations on the Moon, then rocket them back to orbit and rendezvous with the command module. The lunar module—known as the "lem," abbreviated LM—was being designed and built on Long Island, at the same factory where, 20 years earlier, Grumman Corporation had produced 12,275 Hellcat fighters for World War II.

As Grumman conceived the lunar module, it was a two-stage spacecraft; the full ship would land on the Moon, but only the small upper stage and crew compartment would blast off from the Moon and return the astronauts to the command module, in orbit. So the lunar module had two rocket engines, a big one to land the ship, and a smaller one to blast the crew compartment back into orbit. Each of those rocket engines weighed less than the engine in a typical midsize car—and each was a marvel. The descent engine could be throttled: powerful thrust to bring the lunar module down to the Moon from orbit, and lower thrust to allow the LM to hover near the surface of the Moon while the astronauts picked a final landing spot. No rocket engine before had ever had variable power. The smaller engine, which would return the astronauts to the command module, absolutely had to work when the launch command was given. If it didn't ignite, the astronauts were trapped on the Moon. So the ascent engine was a study in simplicity to reduce the number of ways it could fail.

The lunar module would have sophisticated navigation,

electronics and life-support systems, and it would also have storage lockers for bringing home Moon rocks. By 1964, the design was already evolving. The cabin had already been refined to accommodate bulky spacesuits; the seats had been eliminated, and the windows made smaller, to reduce weight; the LM had gone from having five legs, which would have provided maximum stability, to having four legs, which allowed room for bigger fuel tanks.

The LM was, in fact, perhaps the strangest flying craft ever created. It was the first, and remains the only, manned spacecraft designed solely for use off Earth. It would never have to fly through an atmosphere, so it didn't need the structural robustness that would require. It also didn't need to be aerodynamic. It would only fly in space, and then it would be left in space or on the Moon's surface.

The lunar module's other significant challenge was that it could never be test-flown before being used for its critical role. There's no place on Earth to take a spaceship designed for flight in a zero-gravity vacuum and fly it around. So the people who would pilot the lunar modules to the Moon never practiced flying them, except in simulators, which were designed and built by people who had never flown a lunar module.

In the end, Grumman manufactured 14 flight-ready lunar modules. The company that during World War II had been able to produce 14 Hellcat fighter planes a day needed a decade to produce 14 spaceships. That's a measure of the learning curve, to be sure, but also a measure of the difference in complexity between a high-performance warplane and a high-performance spacecraft.

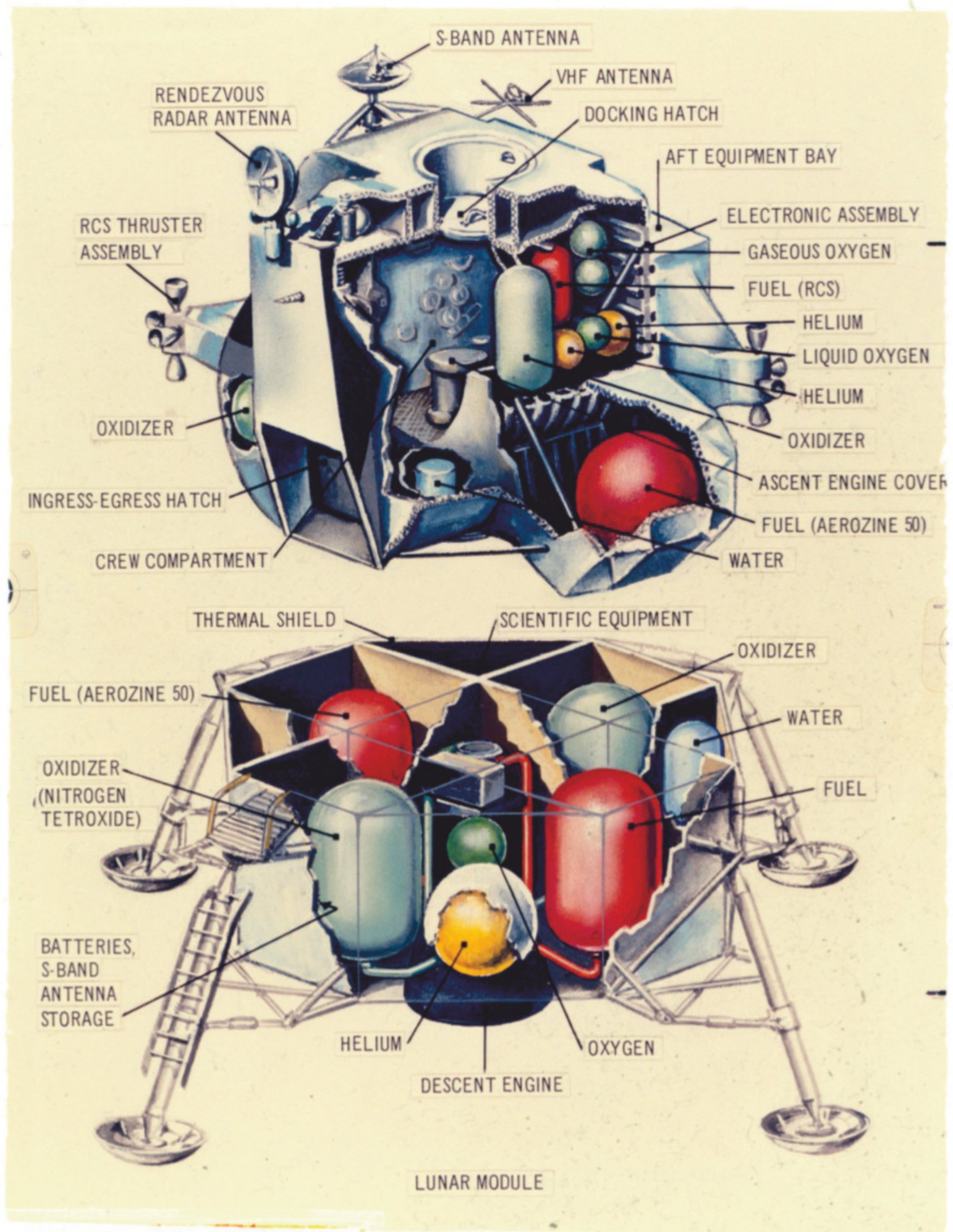
Ten of the flight-ready lunar modules Grumman built flew in space, and six of those landed on the Moon. The total cost of the lunar modules was \$1.6 billion (\$11 billion in 2019 dollars); each one cost \$110 million, although by the time lunar modules were flying to the Moon, Grumman said it could produce a new one for just \$40 million, if anyone wanted one.

Given how novel the machine was, and how novel its flight profile was, one thing that's surprising is how little the astronauts talked about the experience of actually flying it. When you read the mission transcripts during the time astronauts were in the lunar module and flying it, the experience itself is so demanding and so absorbing that there's almost no idle time and no idle exchanges with Mission Control.

Neil Armstrong, just after blasting off from the Moon in Apollo 11's LM, said, "The Eagle has wings." And as Pete Conrad and Alan Bean rocketed back off the Moon in Apollo 12, in the lunar module they had given the call sign Intrepid, Conrad radioed perhaps the only line that the folks at Grumman, or the lunar modules themselves, needed: "I tell you, Houston, I sure do enjoy flying this thing."

FOR THE FIRST MOONWALK EVER, Sonny Reihm was inside NASA's Mission Control building, watching every move on the big screen. Reihm was a supervisor for the most important Moon technology after the lunar module itself: the spacesuits, the helmets, the Moonwalk boots. And as

The lunar module that carried astronauts from the command module to the Moon surface was an engineering triumph. The Grumman team who designed it donned spacesuits to try out ideas for exiting the 10.5-foot distance from the main hatch to the Moon itself.



NASA 68-HC-280

Neil Armstrong and Buzz Aldrin got comfortable bouncing around on the Moon and got to work, Reihm got more and more uncomfortable.

The spacesuits themselves were fine. They were the work of Playtex, the folks who brought America the “Cross Your Heart Bra” in the mid-1950s. Playtex had sold the skill of its industrial

division to NASA in part with the cheeky observation that the company had a lot of expertise developing clothing that had to be flexible as well as form-fitting.

It was when the cavorting started on the Moon that Reihm got butterflies in his stomach. Aldrin had spent half an hour bumping around in his spacesuit,

CONTINUED ON PAGE 72

**MEXICO'S MOST IMPORTANT LIVING ARTIST MIXES
MAGICAL REALISM WITH PASSIONATE REBELLION**





TOLEDO

EL

MAESTRO

FRANCISCO



BY PAUL THEROUX

WHEN FRANCISCO TOLEDO HEARD that a McDonald's was to open in the elegant, nearly 500-year-old Zócalo, or town square, the heart of Oaxaca City, he devised an ingenious method of protest: He announced that he would take off all his clothes and stand naked in front of the site of the proposed Golden Arches. And to remind Mexicans of the pleasures of their own food he would enlist the help of some fellow artists and hand out free tamales to anyone who joined the protest.

"We resisted with him," the Oaxacan painter Guillermo Olguín told me. "We showed that civil society has a voice. We bought banana leaves. I made some posters. We were the soldiers to represent the people. We set up tables. It was a happening!"

Hundreds of people marched in the 2002 event, raised their fists and chanted, "Tamales, yes! Hamburgers, no!" In the end, there was such a public outcry that Toledo did not find it necessary to take off his clothes—the tamales did the trick.

In 2014, Toledo protested again, over a far more serious matter, the disappearance of 43 students in Ayotzinapa, in the state



Toledo's self-portrait *Eye of the Beholder* (2017) uses gold leaf in a grid of refracted identities. The bronze deer figurine (above) wears a whimsical Toledo detail: shoes.

of Guerrero, presumably murdered by the local police, with the connivance of drug cartels. When it seemed that no one in the government cared very much (and indeed might have been involved), Toledo painted portraits of the students on 43 kites, and encouraged people in Oaxaca to fly these works of art as protests. And so “Ayotzinapa Kites” was another happening that raised awareness as it memorialized the victims.

“He’s a giant,” Olguín said. “All the people in Mexico involved in the creative process should be grateful to him.”

An artist, an activist, an organizer, the embodiment of Oaxaca’s vortex of energy, and a motivator, Toledo is known as El Maestro. That is an appropriate description: the master, also teacher and authority figure. His work, and the results of his campaigns and his philanthropy, can be seen everywhere; but the man himself is elusive. He hides from journalists, he hates to be photographed, he seldom gives interviews, he no longer attends his own openings, but instead sends his wife and daughter to preside over them, while he stays in his studio, unwilling to speak—a great example of how writers and artists should respond—letting his work speak for him, with greater eloquence.

It is said that Toledo courts anonymity, not celebrity. He is that maddening public figure, the person so determined to avoid being noticed and to maintain his privacy, that he becomes the object of exaggerated scrutiny, his privacy constantly under threat. It is the attention seeker and the publicity hound who is consigned to obscurity—or ignored or dismissed. The recluse, the shunner of fame, the “I just want to be alone” escapee—Garbo, J.D. Salinger, Banksy—seems perversely to invite intrusion. Say “Absolutely no interviews,” and people beat a path to your door.

Fascinated by his work and his activism, I was provoked to become one of those intruders. Incurable nosiness is the true trav-

In Toledo’s culturally rich Oaxaca (the artist and his sister, c. 1945), 16 indigenous languages are still spoken.



For more than 100 self-portraits exhibited in Oaxaca in 2017, Toledo produced many works, including this ceramic, in the five months preceding the show.

eler’s essential but least likable trait. I put in a request to see Toledo, through his daughter, Sara, and looked further into Toledo’s public life.

He remains a fully engaged artist, expanding a protean output—there are around 9,000 documented works—that defines a titan spanning 20th- and 21st-century art. “Toledo has no limitations,” says William Sheehy, director of the Latin American Masters gallery in Los Angeles, who first encountered the artist’s work 40 years ago. The real comparison, he adds, is “with Picasso.”

Mingling influences from Goya to Klee with his roots in the fabulism and folk traditions of Oaxaca, Toledo’s work bears the stamp of a galvanic life force. “He has transposed his observations into a language of his own,” says Sheehy, “fusing the human and natural worlds of his childhood—it’s all about connectivity.”

Yet he has not ceased to protest—these days the abuses of trade agreements, especially the prospect of U.S. companies introducing genetically modified corn into Mexico and thus undermining the integrity of age-old strains of native corn. One of his protest posters shows Mexico’s revered 19th-century reformer, Benito Juárez, sleeping on eight or ten ears of corn and above him “*Despierta Benito!*” (“Wake Up Benito!”) and “*Y di no al maíz transgénico!*” (“And reject genetically modified maize!”).

These preoccupations give some indication of Toledo’s passion. From the age of 9, when he was singled out in his school for his exceptional drawing ability (the picture happened to be a portrait of Juárez), Toledo has worked almost without a break, that is, 70 years—he turns 79 this July. He works in every conceivable medium—oil, watercolor, ink, metal; he makes cloth puppets, lithographs, tapestries, ceramics, mosaics and much more. He may produce a canvas depicting a vintage sewing machine, fragmented into Cubist-inspired components; create a ceramic of a mysterious bovine morphing into a kind of Minotaur; or paint a rushing river glistening with gold leaf and roiling with skulls.

Though his paintings and sculptures sell all over the world for fabulous prices, he has not enriched himself. He lives simply, with his wife, Trine Ellitsgaard Lopez, an accomplished weaver, in a traditional house in the middle of Oaxaca, and has



“HE WORKS ALL THE TIME. HE’S STILL PAINTING. HE’S MULTITASKING.”

a photographic archive (Toledo is also a distinguished photographer), a rare book library, a shop that made handmade paper for his prints, an environmental and cultural protection nonprofit organization. One library devoted solely for the use of the blind, with books in Braille, is named Biblioteca Borges, after the blind Argentine writer.

Most of these institutions charge no admission. Toledo believes that anyone who wishes should be allowed to enter these places and enlighten themselves, free. A country boy himself, he hopes that people from small villages, who might be intimidated by museums and forbidding public institutions, will visit and look at art produced locally.

SARA PROMISED TO HELP arrange the meeting. She was tall, half-Danish, preparing me for the visit, explaining that her father had not been well. She said that it was in my favor that her father knew that 18 of my books, both in Spanish and English, were on the shelves of IAGO.

Another reason for my seeing Toledo was that he was less than a year older than I. As the years have passed I have nurtured a special feeling for anyone close to my age. It means that we grew up in the same world, in the austere aftermath of World War II, that we knew the same terrors and tyrants and heroes, as well as the same cultural touchstones, certain books, certain fashions, items of slang, the music of the '50s. We were in our early 20s in the tumble and conflict of the '60s, witnessed the civil rights struggle, nuclear testing, Vietnam, the women's movement and, distrustful of the received wisdom of the past, we discovered new ways of looking at ourselves and the world. We were hopeful, seeing oppressive institutions shaken up, and decolonization in Africa. We had lived through an era when authority was challenged by some activists like us, from the margins of society.

Toledo, whose origins were obscure and inauspicious, was the son of a leatherworker—shoemaker and tanner. He was born in Mexico City, but the family soon after moved to their ancestral village near Juchitán de Zaragoza in the Isthmus of Tehuantepec, nearer to Guatemala than to Mexico City—and being ethnically Zapotec, nearer culturally to the ancient pieties of the hinterland too. Though widely traveled (“Actually we grew up in exile”), he claims Juchitán as his home, saying, “You’re from where you feel you’re from.” The Toledo family kept moving, finally settling in Minatitlán near Veracruz, where his father set himself up as a shopkeeper. Toledo was a dreamy child, much influenced by Zapotec

used his considerable profits to found art centers and museums, an ethnobotanical garden and at least three libraries.

IAGO is one of a number of cultural institutions that Toledo had founded—the Instituto de Artes Gráficas, a graphic arts museum and library housed in a colonial building across from Oaxaca’s famed Santo Domingo Church, dating back to 1571. A contemporary art museum, MACO, is another, along with

ALL ARTWORK USED WITH PERMISSION OF THE ARTIST. PP. 36-37: PHOTO COURTESY OF LATIN AMERICAN MASTERS, PRIVATE COLLECTION; P. 37: VENADO CON ZAPATOS (1970). PHOTO: ANGELA CAPARROSO / GALERIA ARVIL; P. 38: COURTESY FRANCISCO TOLEDO; P. 39: TRINE ELLITSGAARD



MASTER OF ALL

Toledo's virtuosic command of materials underscores his inventiveness. From left: *La Madre de los Alacranes* (Mother of the Scorpions) (1976), a fantastical assemblage incorporating turtle shells and crab claws, painted with images of the venomous arachnid; *Vaca Mala* (Bad Cow), undated, mixed media with sand, featuring a bovine who spilled the milk; *Fin de Otoño* (End of Autumn) (1978), a geometric painting punctuated by a depiction of a Oaxacan grasshopper.



"WE SAW THE IMAGES OF OROZCO AND RIVERA. I LIKED TO MAKE DRAWINGS ON THE WALLS."

myths and legends, and the wildlife and flora of a rural upbringing—elements that emerged in his art to the extent that he has become one of the greatest interpreters of Mexican mythologies. His work is filled with the many Zapotec deities, the bat god, the gods of rain and fire, and the sacred animals—rabbits, coyotes, jaguars, deer and turtles that make much of his work a magical bestiary.

Recognizing young Francisco's talent, his parents sent him to Mexico City to study the techniques of graphic art at the Instituto Nacional de Bellas Artes. He was just 17, but even so he was singled out by critics and connoisseurs for his brilliance and held his first solo exhibitions two years later, in Mexico City and in Fort Worth, Texas. Restless and now solvent, ambitious to know more, but still young—barely 20—he went to Paris, to continue painting, sculpting and printmaking.

In Paris he was mentored by another Mexican expatriate, and fellow Zapotec, Rufino Tamayo, and later worked in the atelier of the English expatriate printmaker Stanley Hayter, learning copper engraving. After Toledo's first Paris show,

in 1936, the influential French novelist and art critic André Pieyre de Mandiargues wrote, "The great and very pleasant surprise that we had in our first encounter with this Zapotec Indian was that of finally discovering a sort of genius in the arts, comparable in some ways to 'the divine facility' of certain masters. . . ." And he went on, "I know of no other modern artist who is so naturally penetrated with a sacred conception of the universe and a sacred sense of life." This was a vital endorsement, because Mexican writers and painters seldom gain recognition at home until they've been praised abroad.

Nostalgic less for the big world of Mexico than his remote ancestral pueblo, Toledo abandoned Europe and returned home in 1965—first a spell in Juchitán determined to promote and protect the arts and crafts in his native state of Oaxaca (he designed tapestries with the village craftsmen of Teotitlán del Valle), and then moving to Oaxaca City, where he helped create a cultural awakening, with his indignation and his art. Though he returned to Paris later for a period, and lived and worked in the 1980s in New York City and elsewhere, Oaxaca remains his home.



P. 40: GALERIA JUAN MARTIN. PHOTO: ARCHIVA GRACIELA TOLEDO; PRIVATE COLLECTION. PHOTO: ©CHRISTIE'S IMAGES / BRIDGEMAN IMAGES;
P. 41: GALERIA JUAN MARTIN / COURTESY GALERIA ARVIL

The earthquake that had destroyed parts of Mexico City in September 2017 also laid waste to an enormous section of the city of Juchitán, and moved him to action again.

And she explained that the soup kitchens were not an entirely outside effort—a charity, doing everything—but rather a cooperative system, mostly operated by the Juchitán people themselves, with finance from Toledo. “Having something to do was therapeutic for them,” Sara said. “It took their mind off the earthquake.”

I ARRIVED EARLY ENOUGH to have a brisk walk-through of the new show and was dazzled by the variety of works—iron sculptures hung flat against the wall like trellises of metal filigree, posters with denunciations in large letters, hand puppets, hats, lithographs of mottoes, dolls in Zapotec dresses, a felt corn-cob labeled Monsanto, with a skull on it, and serene ink drawings—a large one completely covered with a shoal of beautifully rendered darting shrimp, flashing to one edge of the paper.

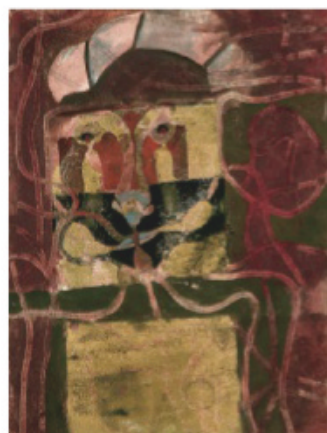
The first thing, the most obvious aspect of the man, was his head—a large, imposing head, familiar to anyone who knows his work, because Toledo has painted hundreds of self-portraits. With an intense gaze, accentuated by a tangled nest of



Drawn From Life

A large, dark, carved wooden sculpture of a seated figure, possibly a deity or a person of high status, with a prominent beard and a large, rounded, shell-like structure behind the head. The figure is seated, with its hands resting on its knees. The sculpture is made of a dark, polished wood, possibly ebony, and is set against a plain, light-colored background. The figure has a large, rounded, shell-like structure behind its head, which could represent a helmet or a decorative element. The figure's face is highly detailed, with a prominent beard and a serious expression. The figure's body is also highly detailed, with visible musculature and a large, rounded, shell-like structure behind the head. The figure is seated, with its hands resting on its knees. The sculpture is made of a dark, polished wood, possibly ebony, and is set against a plain, light-colored background.

1996 *Self-Portrait, El Viejo*



A stylized, abstract painting of a man in a black hat and a light-colored shirt, holding a small, dark, abstract figure. The background is a deep blue. The man's face is yellow with dark, expressive features. The shirt is light blue and white with dark, angular patterns. The small figure is dark and abstract, possibly representing a child or a pet. The overall style is reminiscent of mid-20th-century abstract art.

An abstract painting by Francis Bacon titled 'The Face'. The composition is dominated by a central, circular, multi-colored form that resembles a face, rendered in a distorted, almost cubist style. The colors are vibrant and varied, including shades of blue, red, yellow, and black. The background is a mix of warm, earthy tones like ochre and brown, with some cooler blue and white areas. The overall effect is one of intense emotional expression and visual complexity.

1995 *Self-Portrait* 57

wild hair, the head is much too big for his slender body, the slight torso, thin arms, skinny legs, looking doll-like and improbable. He seemed cautious and subdued, but courtly, austere, polite in the manner of old-fashioned Mexicans. I also felt at once, seeing his crooked smile, and the way he bounced when he walked, that he had too much heart and humor to make himself unapproachable. Some people—Toledo is one—are so naturally generous they have a justifiable fear of the clutches of strangers.

“This is lovely,” I said, of the drawing.

“*Camarones*,” he said, and tapped the glass of the case it lay in, shimmering with life and movement. “I like the way they swim together. You see the pattern?” And as though this explained everything, he added, “Juchitán is near the sea.”

He signaled to his daughter and made a sign with his fingers that indicated coffee drinking.

He became animated, smiling, as we walked around the exhibition. At the “*Despierta Benito!*” protest poster, he said, “This is against the government.”

A lithograph under glass was a copy of a 17th-century Spanish manuscript listing a Zapotec vocabulary, for the use of missionaries and officials. Another was also based on an old document, but one with images of men and women, their legs and hands in shackles and chains, titled *De la Esclavitud* (*Of Slavery*). His collages were arresting and multilayered.

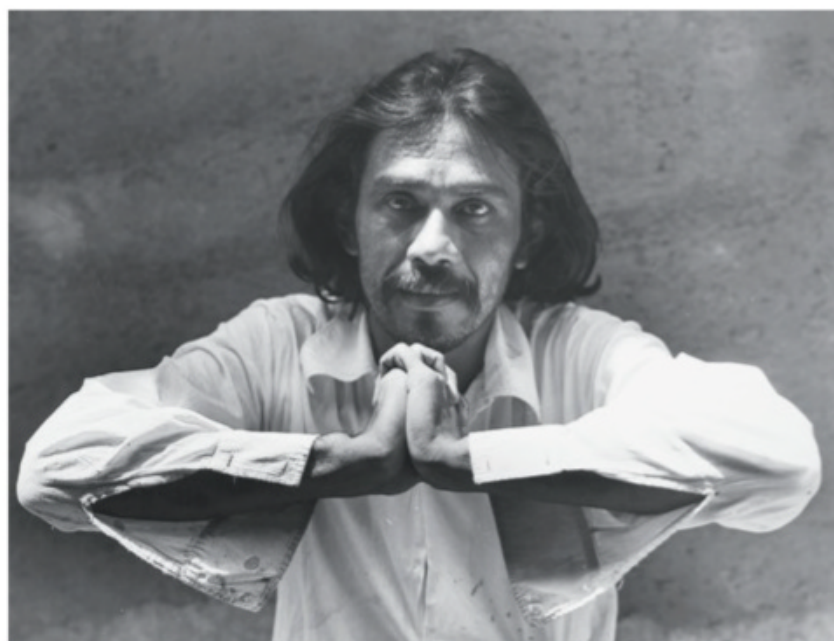
“This is me,” he said of a mass of feathers, “*Autor-retrato en Plumas*,” which when I concentrated I discerned was Toledo’s face picked out in gray feathers, glued to a board, a startling likeness. He laughed as I examined it, a meticulous pattern of pinfeathers. Nearby were some vivid photographs.

“I wanted to be a photographer from the age of 13,” he said. “I saw the *Family of Man* photographs in a catalog in Oaxaca. It opened my eyes! I bought a small camera. Around that time I went to Oaxaca to school. I thought, ‘Maybe I’ll be a photographer.’ I still take pictures.”

“But you drew from an early age, too?”

“Yes, I drew in school. I was 9 or 10. We saw the images of Orozco and Rivera. I liked to make drawings on the walls. My mother didn’t like it, but my father resisted her! And in Oaxaca I discovered a school of fine arts near La Soledad”—Basílica de la Soledad—“The library had books with William Blake images. I loved them, even though I couldn’t read the poems.”

“When my father said, ‘Go to Mexico City,’ I had to start all over again. I was 17 or 18 years old. I was at a school with an art workshop, in the Taller Libre de Grabado [a subsidiary of the National Institute of Fine Arts]. I chose to learn lithography, and I painted at home. But my school had many workshops—weaving, mosaics, murals, furniture, ceramics. I saw that there were so many ways to make art. I lived with a family that took care of me. The sister of that wom-



Toledo (photographed in Cuernavaca, Mexico, in 1981) focuses on creative output, typically insisting when he has completed new work that he does not want the distraction of attending exhibitions.

**“I STARTED OUT HATING
HER. THEN I LATER
BEGAN TO SEE THAT
SHE REPRESENTED
SOMETHING.”**

an was married to a painter. She said, ‘I have a man here who chooses his food by the colors. If he doesn’t like the colors he doesn’t like the food.’”

Toledo paused and smiled at the memory.

“So that man took an interest in me and my work, and introduced me to Antonio Souza, owner of a very famous gallery. Souza let me use his home as a studio. He gave me my first show in 1959—I was 19, and the show went to the States.”

What sort of work was in this first show, I wondered.

“Little paintings—watercolors, of animals and people,” Toledo said. “All my life I’ve painted the same things.”

This simple statement is provable. On one of the shelves at IAGO are four thick volumes (published recently by Citibanamex) cataloging significant Toledo pieces from 1957 to 2017, in more than 2,000 pages, and demonstrating the consistency of his vision and the grace notes of his humor.

Souza told him that he needed to get out of Mexico and see the museums of Europe. “I went to Paris. I went to Rome. The Etruscan Museum in Rome—I visited it many times. In Paris I saw *Waiting for Godot*, when it was first produced, and all the time I was painting.”

His paintings became sought after for their singular beauty. His work resisted all classification and fashion. He was not attached to any movement, even when the art world was turbulent with abstraction and Minimalism and Color Field and Op Art. He elaborated his ancestral visions of masks and folk tales, haunted and highly colored landscapes, and eroticism that was both comic and gothic. “He intuitively feels the timelessness

of authenticity,” the Guatemalan art critic Luis Cardoza y Aragón wrote. In 1967, an enthusiastic Henry Miller—himself a watercolorist—wrote the text for a Toledo exhibition.

“Toledo has created a new visual grammar,” the Mexican writer Juan Villoro told me, when I asked him to assess Toledo’s uniqueness. “His colorful reality is a setting for fables where human beings are accidental witnesses of the real rulers of the world. Grasshoppers and iguanas, coyotes and deer, scorpions and frogs are the masters of that universe. But they don’t live in comfort or in the perfect boredom of paradise. Toledo’s ‘Garden of Earthly Delights’ is a world of troubles, passions, sexual attractions between different and sometimes opposed species. His nature is an enhanced version of the original model. His dreams are not a departure from reality: They are an extreme enhancement of the real.”

Toledo and I were still walking through his new show. Here was a woodcut of two rhinos copulating; in a decorated frame, a cracked mirror (“The sister of Snow White,” Toledo said); the wheel of a spider web spun out of steel wires. Then we came to a portrait of Albrecht Dürer, his hair and beard rendered by Toledo with human hair.

“Dürer was fascinated by hair,” Toledo said simply. Dürer was one of his heroes, he said. I asked which others he admired. Rufino, of course, “and many others.” Then he remembered. “Lucian Freud—very good.”

We came to a large work, of many faces, individual portraits of the 43 students who had been abducted and killed at Ayotzinapa, the faces printed in melancholy tints, like Russian icons, very different from the faces on the “Ayotzinapa Kites.”

“Sad,” Toledo said. “A tragedy.” He steered me out of the exhibit to a small table, where two cups of coffee had been placed, along with a pile of my books. “Sit—please. You can sign them? For our library.”

I signed the books, and thanked him for meeting me at short notice. I told him he was the only person in Oaxaca I had wished to meet, and when I said this was not simple *adulación*, he dismissed it with a wave of his hand.

“My English is no good.”

“It’s perfect.”

“I’m old, I forget,” he said. “I’m going to stop painting sometime.”

“Please don’t say you’re old,” I said in Spanish. “Because I’m the same age.” And using the Mexican expression for an older person, “We are men of judgment.”

“Maybe. I like to think so,” he said in English.

“I’m interested that you went to Paris when you were very young,” I said.

“Yes,” he said. “But in Paris I was alone, and lonely. I worked, I did painting and prints. Tamayo was kind to me. I felt less lonely with him.”

The renowned Mexican painter Rufino Tamayo had gone to Paris in 1949—fled, perhaps, because he found himself out of sympathy with the passionately political muralists such as Rivera and Orozco, and he was skeptical of revolutionary solutions. Tamayo, wishing to go his own way, took up residence in New York City, and after the war worked in Paris. He encouraged Toledo to paint in his studio, and though Tamayo



Toledo installed his kites with images of 43 murdered students at Mexico City’s Memory and Tolerance Museum in 2015.

**“NO ONE CARES ABOUT
THE POOR, OR THEIR
LIVES. THE GOVERNMENT
DOESN’T CARE.”**

was 40 years older than Toledo, they had much in common, proud of their Zapotec ethnicity, both resisting classification, making art in prints, in painting, in sculpture; and in the end, Tamayo returned to Oaxaca, like Toledo.

“I came back to be among my own people and my family,” Toledo told me. “I wanted to speak Zapoteco again, in Juchitán.”

“So you were happy then?”

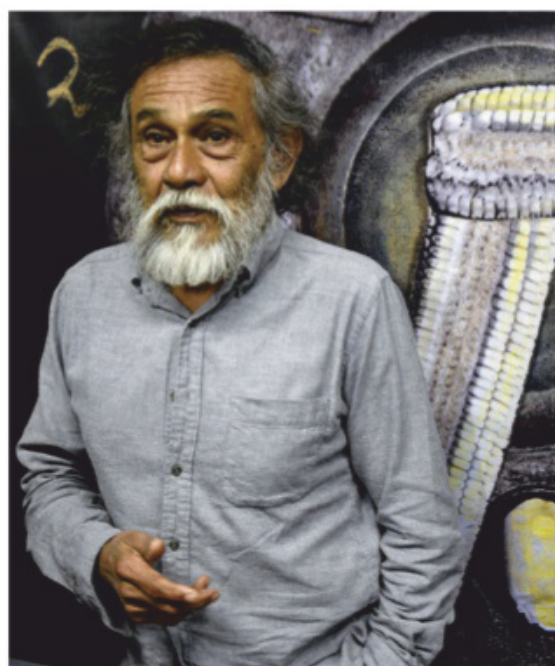
“No. I couldn’t work there,” he said. “It was the noise, too much activity. I liked the place—I was home. I could speak Zapoteco—my grandfather and father and others spoke it. I don’t speak it well—I understand it. But I wanted to paint, so I left.”

“Did you miss Paris?”

He cocked his considerable head. He said, “In Paris I fell in love with a woman. She was Vietnamese. I had an idea. I planned to go to Vietnam with her—this was 1964, when it was very bad there.”



At the Zapata subway station in Mexico City in 2015, Toledo attends an exhibition focused on protesting genetically modified corn.



"What was your idea in going to Vietnam in wartime?"

"Just to see it," he said. "I thought I could teach drawing in classes to American soldiers. And I could meet the girl's parents." He shrugged. "But the girl's parents would not support my application for a visa. So in the end I left Paris. I went to New York City, but I was lonely there too."

I mentioned my feeling of meeting someone my own age, how we had both lived through the events of the 1960s—Vietnam, demonstrations, political and social upheaval. He had experienced at close hand the massacre of students in 1968 in Mexico City and was so outraged by it he removed his paintings from a government-sponsored exhibition shortly after, destroyed some of them and sold others, giving the money to the families of the murdered students.

"You're my age—but you're strong," he said. He clapped me on the shoulder. "Driving your car in Mexico!"

"But I'm sure you drive."

"My wife drives—but me," he tapped his chest regretfully. "My heart."

"What happened to the Vietnamese woman?"

"Funny thing. She married a G.I. and went to live in California," he said. "Now she's a widow, and old, but I still talk to her. She comes to Oaxaca—I see her here, we are friends." He became restless, adjusting his posture on the chair, holding

the coffee cup but not drinking. He said, "Have you seen what is happening in Mexico?"

"I've traveled a little bit—driving around. I drove from the border, stopping in towns and talking to people. I stayed a while in Mexico City. I'm trying to make sense of Mexico."

"Good for you, amigo!" But he said he didn't travel, and he gave me his reasons. "Roads are dangerous. Planes are dangerous. I don't like airports. I don't like the colors of the insides of planes. I don't like the smells."

We talked about Mexico City. He told me of his studies there, and the artists he'd met. I asked him what he thought of Frida Kahlo, because as a budding artist he would have known her work when she was at the center of attention, as an artist, as a public figure, iconic, adored or disputed over—she died in 1954.

"I started out hating her," he said. "Then I later began to see that she represented something. And outsiders were interested in her. Her life was so complex and painful. So she is something," he said. Then as an afterthought, "But there are so many others!"

To change the subject, and suggest a place I'd been, I clicked on my phone and showed him a photograph I'd taken of a tiny peasant woman in a remote mountain village in the Mixteca Alta.

Toledo peered at the photo and frowned. "She's poor," he said. "Nothing will happen to her. No one cares about her, or people like her. No one cares about the poor, or about their lives. The government doesn't care."

He brooded a bit and sipped his coffee.

"Mexico is in a bad time now," he said. "It's not just the U.S. and Trump.

It's other things. Drugs and gangs, and the immigration from Central America." He gestured, spreading his thin arms, his delicate fingers. "Oaxaca is in the middle of it all."

This virile and humorous man, full of life, full of ideas and projects, is an optimist in action and in his art, but a skeptic in thought. He fully acknowledges the human impulse toward self-destruction.

"But you're working," I said. "That's the important thing. Tamayo worked until he was 90."

"He was strong. I'm not," he said. "My studio is here, I'm still painting. I look at the paintings I've done and I'm not that satisfied. I've done so many! I want to move on and do other things."

He got up and led me back into the exhibit, past the metal sculpture and the felt hats, the light box of transparencies of a human

CONTINUED ON PAGE 78

AMERICAN IDYLL

**KICK OFF
YOUR
SHOES AND
JUMP INTO
SUMMER'S
MOST
REFRESHING
TRADITION,
A LAZY
AFTERNOON
AT THE
LOCAL
SWIMMING
HOLE
■ ■**

PHOTOGRAPHS BY GREGG SEGAL

TEXT BY BRET ANTHONY JOHNSTON





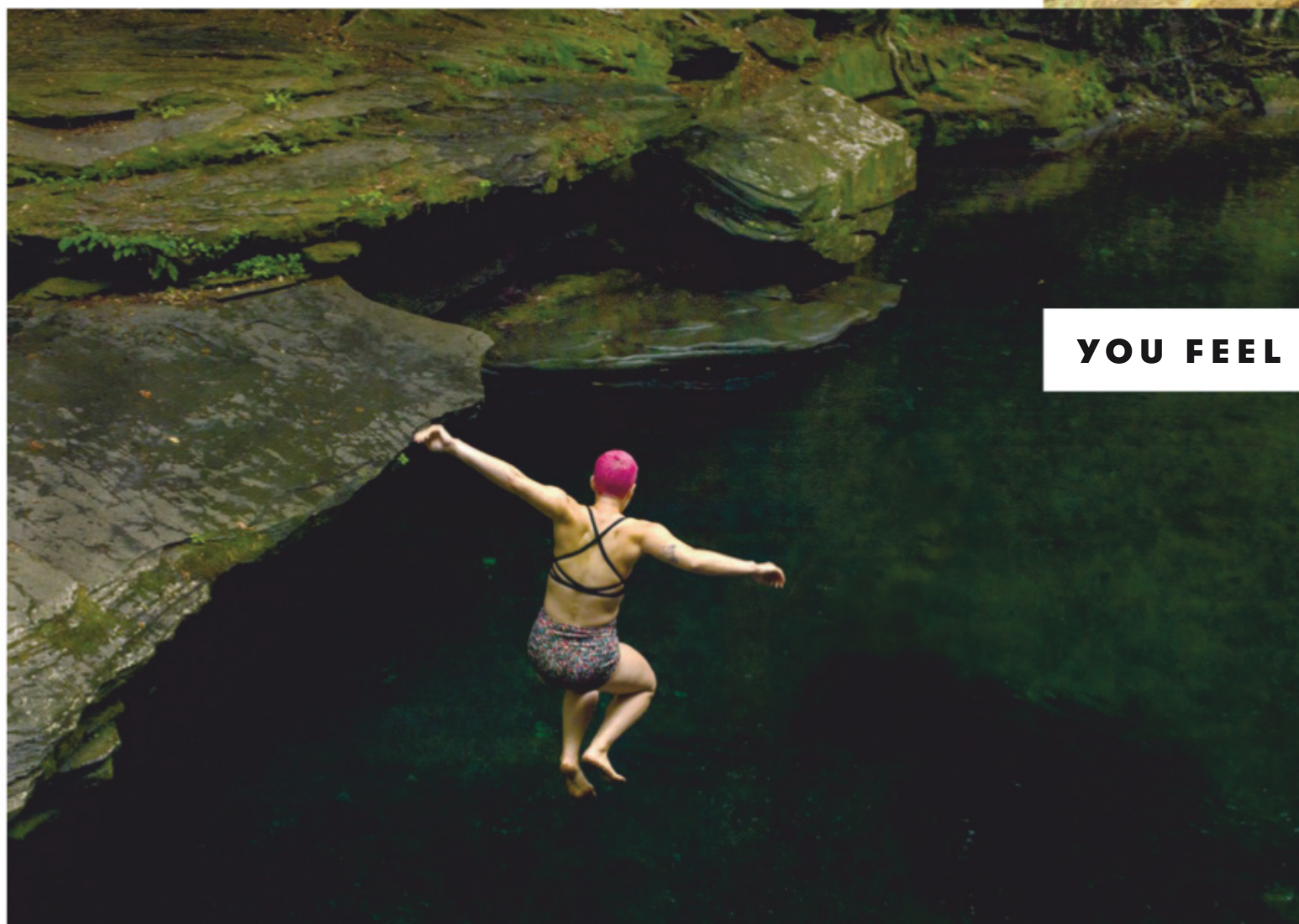
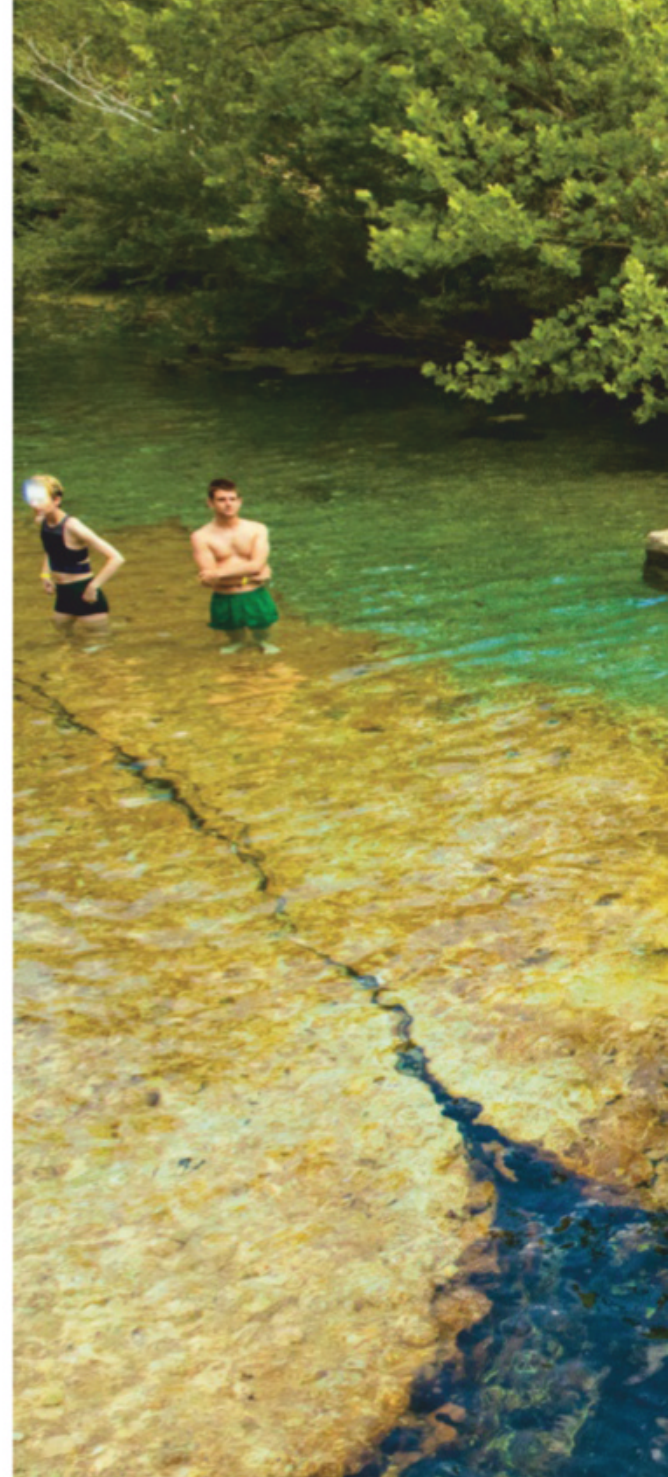
IN THE SWING Blue Hole Regional Park, just south of Austin, Texas, is sought after for its canopy of bald cypress trees and its two rope swings.



I**F YOU LIVE IN TEXAS**, a desire will overtake you on an unforgiving summer afternoon. Wool-thick humidity, heat fumes undulating over asphalt, your truck's air conditioner outmatched. You should be working, but the pull is relentless. It's a current, a wave, a yearning. You want to journey to a quiet place that surprises you with its depths. You want to be among the few people in the world who know where it is. You long to plunge into cool water. You want to splash, to float. You want—no, *need*—a swimming hole.

If you live in Central Texas, Barton Springs and Hippie Hollow make the most sense. Each is gorgeous—the icy spring-fed pool at Barton, the limestone shoreline hemming Hippie Hollow—but ultimately you're drawn elsewhere.

Highway 71 winds through the southwestern edge of Travis County. You pass churches and taxidermy shops and a man in a straw Stetson selling peaches from his pickup. He mops his brow with a red bandanna. Then comes the Barton Creek Habitat Preserve. Cedar and oak crown the uplands, and for a stretch there's



YOU FEEL THE SUDDEN





IMPULSE TO RUN, TO BOLT AND LUNGE INTO THE HIDDEN POOL.



THE PERILOUS AND THE PLACID
 Above: The swimming hole at Jacob's Well in Texas leads to an underwater cave that has claimed the lives of numerous scuba divers. Left: A girl eats homegrown watermelon at Texas' Blanco State Park. Far left: Before the internet, Peekamoose Blue Hole in upstate New York was a local secret. Today it swarms with visitors.



A HIKE THEN A FLOAT

Visitors to California's Natural Bridges, about 130 miles east of San Francisco, have to trek on foot for a mile to reach the park's limestone caverns. The water at the cave entrance is shallow and sunlit, a popular place to lie back and relax on inflatable rafts. Many bolder swimmers venture into the dark recesses of the cave, sometimes outfitted with headlamps.





STONE COLD PARADISE Right: UC Davis students from Malaysia splash in the Yuba River, near Grass Valley, California. Along with spectacular scenery, the park is home to historic gold rush sites. Far right: The limestone grotto of Hamilton Pool, west of Austin, Texas. Entry to the popular spot now requires online reservations.



a semblance of shade. How easily you can imagine the descent into the canyon, the sugarberry and pecan trees leading down to the pristine creek. The prospect leaves you lightheaded. If you pull into the preserve now, you'll be in clear cool water within ten minutes. Still, you drive. The steering wheel burns. The AC sputters. You click it off, lower the windows. The air rolls in hot and loud. A web of sweat spreads across your neck. Your shirt dampens against the seat. You smell Texas elm, the parched earth, baking grasslands.

When you arrive, birdsong: water-thrush and golden-cheeked warbler. A breeze whispers through juniper, lifting and spreading the thin branches. There's also the sweet faraway sound of children laughing. You feel the sudden impulse to run, to bolt through the wooded trail until it breaks into the clearing and you can lunge into the hidden pool. You don't. If anything, you linger. This box canyon is so serene, so lush and mysterious, that it demands reverence. Sprawling ferns, chatterbox orchids, red bay and canyon mock orange. You inhale tranquillity. You bide your time on the trail.



ON THE SURFACE, THE WATER IS WARM AND BEJEWELLED WITH SHIM

Hamilton Pool—otherworldly—formed thousands of years ago when the dome of an underground river collapsed. Now half the jade-blue water is enclosed by the arching remains of a limestone grotto, its ceiling sharp with stalactites. A waterfall spills into the pool, and the sound is so softly consistent that it slows your pulse. When the sun climbs high enough, a rainbow bends through the tumbling water. The colors seem garish compared with the moss-edged outcroppings, the luminous pool and the willing, endless sky.

The swimming hole teems with children and sun-lulled parents, teenagers with braces and men with farmers' tans and





MERING LIGHT.

JUMPING-OFF POINT

The cliffs at Vermont's Warren Falls form natural diving boards of varying heights: 10, 15, 20 and even 50 feet. The area used to be a local secret, but ever since 2015, when *USA Today* designated it the fourth-best swimming hole in America, Warren Falls' small parking lot has been filling quickly on warm summer days.





white-haired grandparents, all of them delivered here by the same longing. You wade out. You roll onto your back and push off the sandy floor. On the surface, the water is warm and bejeweled with shimmering light, but it's cooler beneath. It folds over your shoulders like draped silk. The waterfall thrums louder, and louder still. The sun drags over you. You close your eyes. You float.

A cliff swallow's whistle, the wafting scent of sunscreen, water sliding through your fingers and between your toes. The pool bears your weight, conveys you toward its center, and as it does, you become keenly aware of the abundance of unseen life

OFF THE WALL
The marble that once filled Dorset Quarry in Vermont was used to build the New York Public Library, among other structures. After the quarry closed around 1917, it filled up with spring water and became a popular swimming spot. ■■



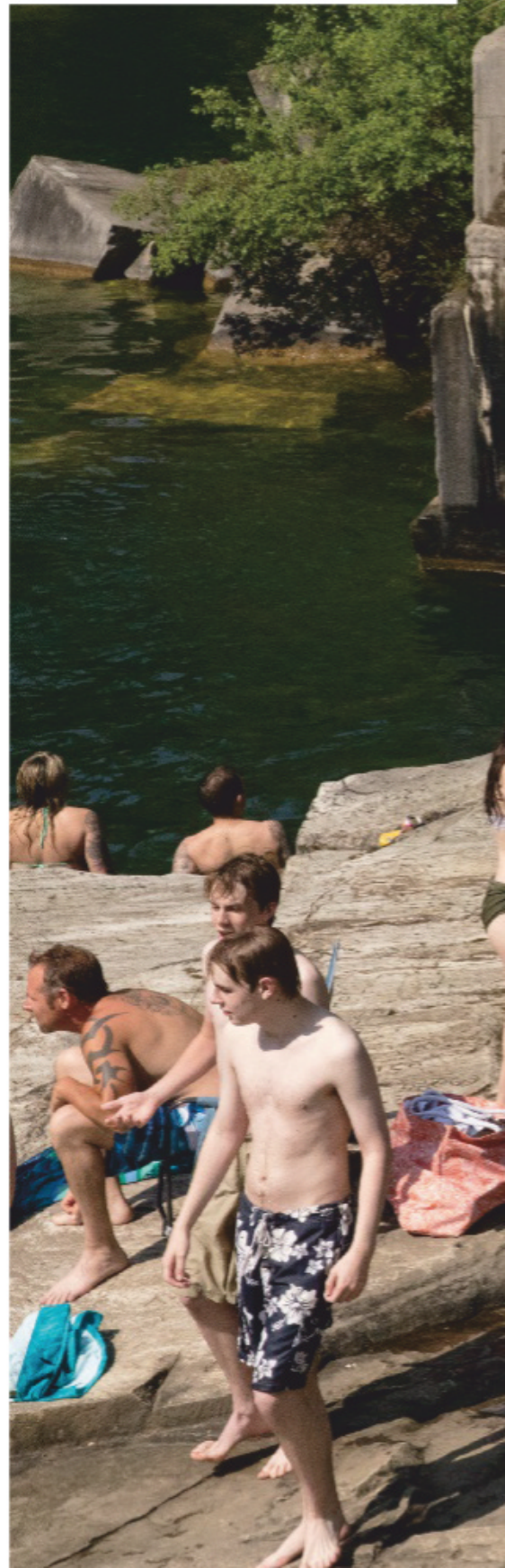
IN THE POOL, PAST AND FUTURE DISSOLVE. THERE IS ONLY THIS MOMENT.



DOG DAYS OF SUMMER

Bethel, Maine, draws most of its visitors during ski season, but in the summer, regional tourists flock to Frenchman's Hole, a dog-friendly spot carved out by a waterfall. ■■

all around you—the fish and turtles underwater, the myriad creatures in the box canyon—and every one of your fellow swimmers. You realize this is why you made this trip, why the pull would not relent. You wanted—needed—to immerse yourself in such long-traveled water. In the thick of a Texas summer, to float in a swimming hole is to feel so relaxed, so connected to the good in the world that you're rinsed of time. In the pool, past and future dissolve. There is only this moment. You are drifting, slow and directionless, content to travel wherever the pool decides. You are cool in the hot sun, and for now, for as long as you stay in this perfect water, you are not alone. ♦







R

>
A rendering of
OceanGate's
Titan submersible
exploring the deck
of the *Titanic*.
—

THE
DAREDEVIL INVENTOR
BEHIND THE WORLD'S FIRST
DEEP-DIVING PASSENGER
SUBMARINE SETS HIS SIGHTS
ON THE MOST FAMOUS
SHIPWRECK
OF ALL

RETURN



TO THE

TITANIC

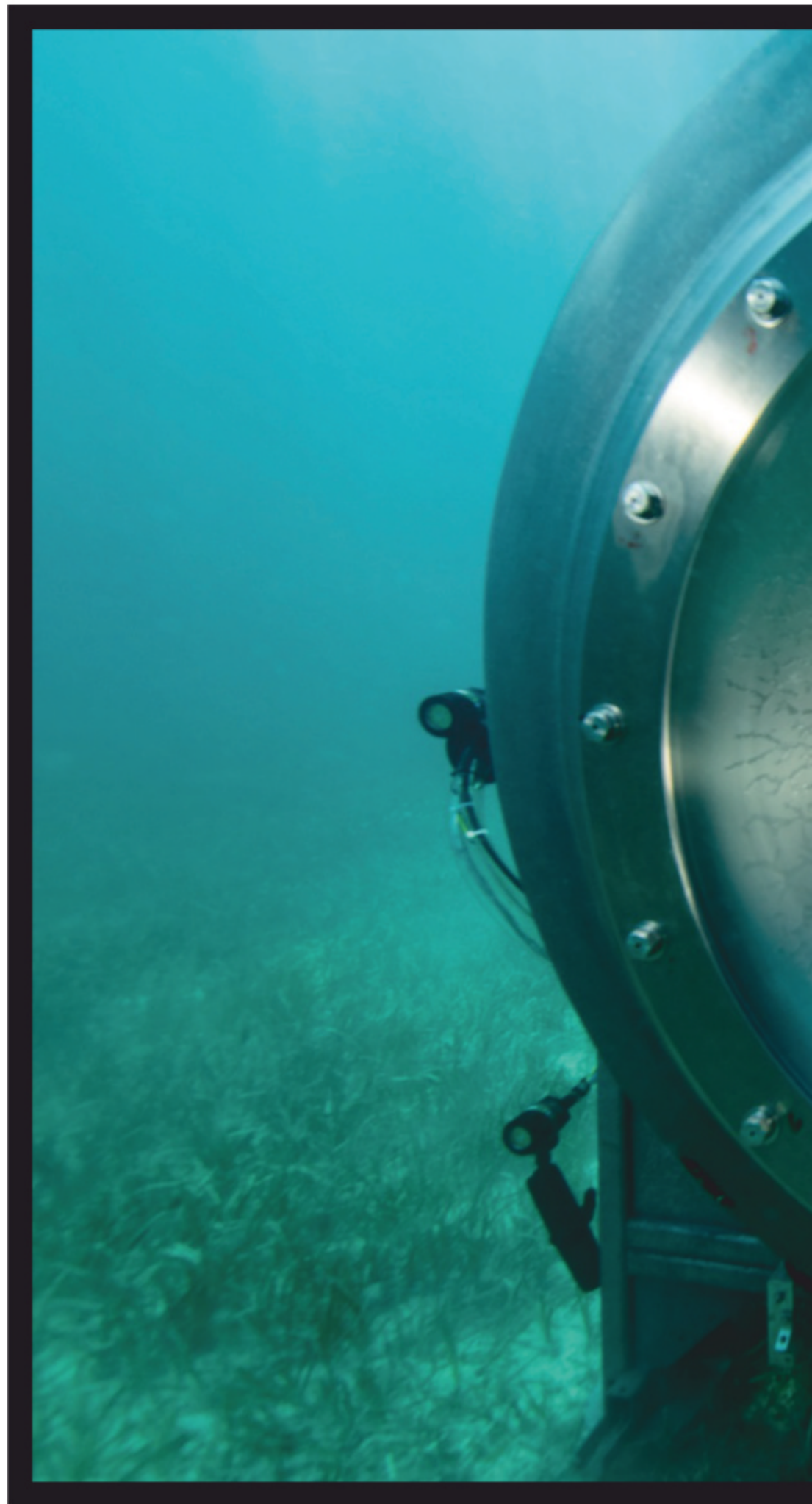
BY TONY PERROTTET



THE WORLD LOOKS VERY DIFFERENT through the eye of the Cyclops. I learned this one freezing morning this past February, after trudging through two feet of snow to get to the marina in Everett, Washington, a small port 45 minutes north of Seattle. On the dock was a cylindrical white pod about the size of a moving van, a five-person submersible whose protruding, semi-spherical window inspired its name, after the monocular monster of myth. A half-dozen men wearing thickly padded khaki jumpsuits and orange helmets gathered on the snow-covered dock ready to send me under the ice-flecked waves of Puget Sound.

The schedule was as rigorously timed as a rocket launch. “Vessel prep” had been completed at dawn, so after a pre-dive briefing, I climbed a ladder to the top hatch of the sub, took off my boots and clambered into the tube, which was sheathed in perforated stainless steel. Inside, the pilot Kenny Hague was checking instruments, including the modified Sony PlayStation controllers used to steer the sub underwater. There were no seats, but with only three of us on the dive (the other was staff member Joel Perry), I could stretch out like a pasha on a black vinyl mat.

With the submersible still resting on its metal launching platform, one end of the platform slowly rose from the dock and we slid backward into the sea. The milky green waters of Puget Sound rose over the eye of *Cyclops 1*; the support team blurred and vanished, followed by the leaden sky. Even though



PHOTOGRAPHS BY BECKY KAGAN SCHOTT

visibility was only about 15 feet, thanks to storm runoff, a condition my crew mates dubbed “the milkshake,” it was still magical to be breathing underwater, an unnatural human state that has captured our imagination since antiquity, when Greek legends of Poseidon and mermen abounded. I was reminded, inevitably, of Jules Verne’s *20,000 Leagues*



Under the Sea, and Captain Nemo's near-mystical reverie on the *Nautilus* over its mastery of the deep: "The sea is everything. . . . It is an immense desert, where man is never lonely, for he feels life stirring on all sides. The sea is only the embodiment of a supernatural and wonderful existence. It is nothing but love and emotion; it is the 'Living Infinite.'"

This test "dunk," in the words of my hosts, from a

▲
Stockton Rush
peers out
through *Titan*'s
viewport during
a test dive. It's
the largest view-
port of any pri-
vate deep-diving
submersible.
—

company called OceanGate, was just a taste of what will happen this summer, when OceanGate will begin taking paying customers to visit the fabled wreckage of the *Titanic*, which lies some two and a half miles beneath the North Atlantic. The experimental submersible for those trips, named *Titan*, closely resembles its sibling *Cyclops 1*. But *Titan* is the first deep-sea submersible constructed from a carbon-fiber

P. 58-59: OCEANGATE

composite, which allows the vessel to withstand enormous pressure at great depths while being far cheaper to build and operate than more traditional subs of equal abilities. Though the average depth of the world's oceans is 2.3 miles, or a little more than 12,000 feet, until *Titan* came along only a handful of active submersibles were capable of reaching that depth, and they were all owned by the governments of the United States, France, China and Japan. Then, last December, OceanGate made history: *Titan* became the first privately owned sub with a human aboard to dive that deep and beyond, finally reaching 4,000 meters, or about 13,000 feet—a little deeper than where the *Titanic* lies.

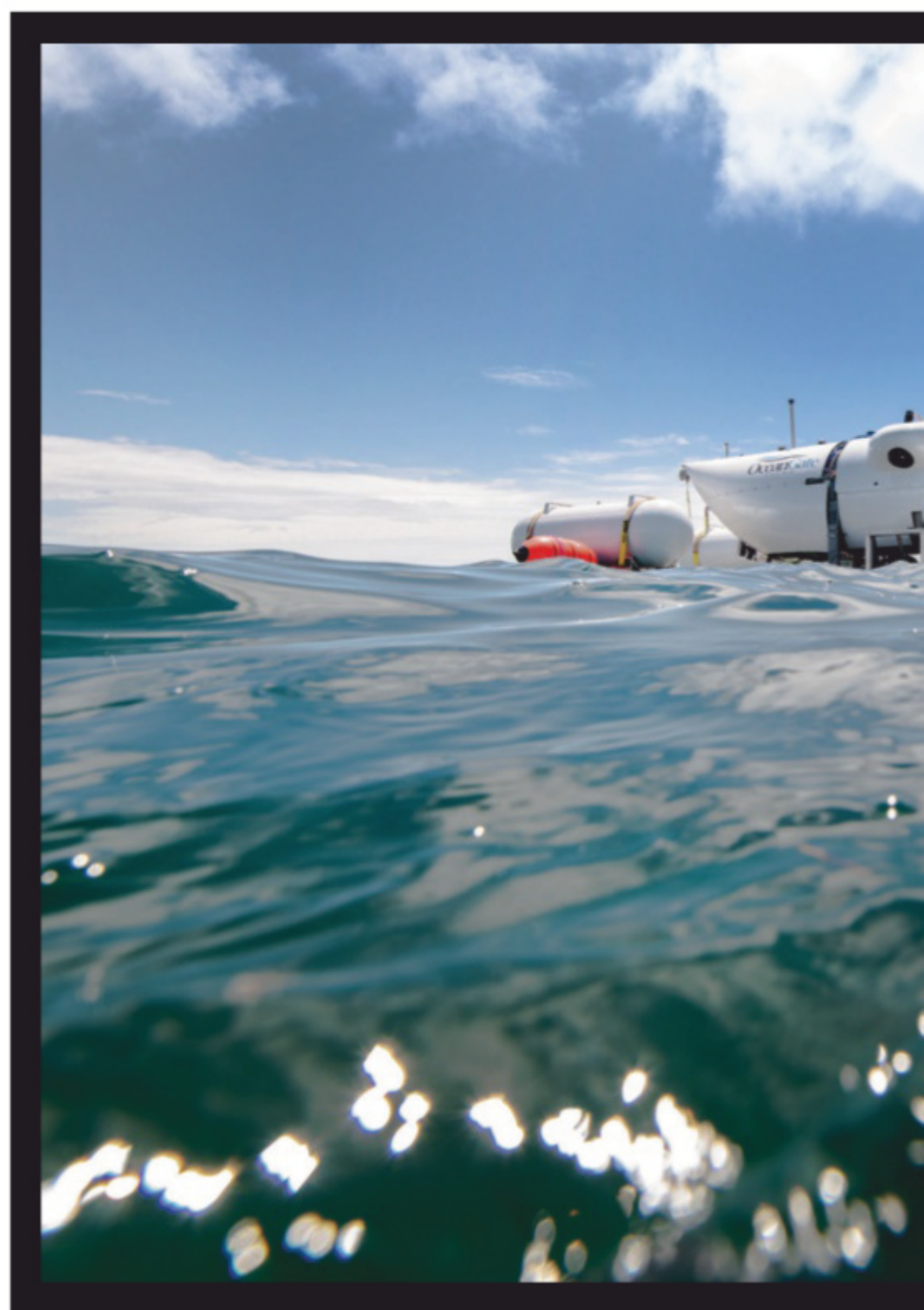
The feat was the culmination of a dream for Stockton Rush, OceanGate's maverick CEO and co-founder. "Stockton is a real pioneer," says Scott Parazynski, a 17-year NASA veteran, the first person to have both flown in space (five times) and summited Mount Everest, and a consultant on the *Titan* expeditions. "It's not easy to take a white sheet of paper, come up with a new submersible design, fund it, test it and mature it. It was an incredibly audacious thing to do."

In his zeal for innovation, Rush stands out even in the elite manned submersible community, which attracts wealthy and eccentric individuals willing to risk their fortunes on wildly uncertain endeavors. Rush wants to do for deep ocean exploration what Richard Branson, Jeff Bezos and Elon Musk are doing for space travel. By taking well-heeled tourists to the deep—at first, each seat cost \$105,129, the inflation-adjusted price of a first-class ticket on the *Titanic*, though the rate has increased to a cool \$125,000—Rush hopes to use private enterprise to spur advances in the long-neglected field of underwater exploratory technology, and reveal some of the secrets of the great blue unknown.

Not that he is given to romantic reveries of the sea. "Sometimes Mother Nature works for you," Rush said, smiling wryly as he settled into a chair in a wood-paneled parlor in downtown Seattle. "And sometimes Mother Nature is a bitch." The vagaries of the weather are an ongoing theme for Rush, with deluges, lightning storms and other cataclysms wreaking havoc on *Titan*'s test schedules. But he was also referring to the difficulties of our meeting, which occurred while Seattle was being pummeled by its snowiest month in half a century, turning roads into rivers of slush and paralyzing transportation. Just reaching a place for us to sit down had the air of an arctic trek in the Edwardian Age, one reason we chose the historic Hotel Sorrento, which was built for the 1909 Alaska-Yukon-Pacific Exposition that put Seattle, then a frontier outpost for gold prospectors and fur-trappers, on the map. Ever since, the city has attracted independent thinkers, inventors and misfits with a spirit symbolized by the iconic Space Needle, built for the 1962 World's Fair. As we chatted, snow cascaded down outside the hotel window, cocooning us in an eerie silence and creating the sense that we were sitting in a sub on the ocean floor.

With a shock of silver hair and preppy clothes, Rush might be mistaken for a corporate lawyer on casual Friday rather than

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OCEAN"



an ocean adventurer in the mold of a Jacques Cousteau, who was not just a telegenic explorer but also an inventor (of the aqualung, in his case). A conversation with Rush jumps between engineering ("sacrificial weights," "tensile forces," and "fairing," the external shell added to streamline a sub), business ("marketing granularity") and boyish enthusiasm (Rush has a fondness for "Star Trek" references).

His childhood dream, growing up in a wealthy San Francisco family, was to be an astronaut. His parents assumed he'd grow out of it. "I didn't," he says. When Stockton's father introduced him to Pete Conrad, the commander of Apollo 12 and the first manned Skylab mission (and a personal friend), the astronaut advised the teenage math whiz to get his pilot's license. So in 1980, at age 18, Rush became one of the youngest commercial pilots in the world, then signed up to fly chartered planes in and out of Saudi Arabia, all while studying aerospace engineering at Princeton. "It was the coolest college summer job," he says. For his thesis, he designed a high-speed ultralight aircraft; later, he built his own plane, a Glasair III,



from a kit. (“You start on Page 1 of the manual, and by the time you get to Page 680, you have a plane!”)

The astronaut dream was dashed when Rush learned that his eyesight wasn’t good enough for him to become a military pilot, in the 1980s still the astronaut fast track. Instead, he moved to Seattle, to work for McDonnell Douglas as a flight-test engineer on F-15 fighter jets, then went to business school. Building on inherited money, he invested in a string of esoteric tech companies (wireless remote-control devices, sonar systems). Still, he dreamed of going to space, perhaps as a passenger on one of the private rockets being developed in the early 2000s by the likes of Richard Branson. In fact, Rush traveled to the Mojave Desert in 2004 to watch the launch of SpaceShip-One, the first commercial craft sent into space. When Branson stood on its wing and declared that a new era of space tourism had arrived, Rush says, he abruptly lost interest. “I had this epiphany that this was not at all what I wanted to do. I didn’t want to go up into space as a tourist. I wanted to be Captain Kirk on the *Enterprise*. I wanted to *explore*.”

After it’s towed offshore, Titan’s launch platform is submerged 30 feet with the sub attached. Then the pilot releases the sub from the platform.

AS IT HAPPENED, Rush had been a fanatic scuba diver since he was a teenager, and had ventured to the Red Sea, the Cayman Islands and Tahiti. It dawned on him that Seattle had excellent cold-water diving. “Puget Sound is full of nutrients, so you have sharks and whales and crabs and dolphins and seals and anemones,” he said. “It’s an absolutely incredible place to dive—except that it’s freezing!” He took a cold-water dive class, but was put off by the thick, full-body dry suits and vast amounts of paraphernalia, including multiple air tanks. “I loved what I saw, but I thought, There’s gotta be a better way. And being in a sub, and being nice and cozy, and having a hot chocolate with you, beats the heck out of freezing and going through a two-hour decompression hanging in deep water.”

The obvious next step was to rent a submarine. He was shocked to find that there were fewer than 100 privately owned subs in the world, and only a few were available for charter. He then tried unsuccessfully to buy one. Instead, a London company offered to sell him parts for a mini-sub that could be built using blueprints created by a retired U.S. Navy submarine commander. He completed it in 2006, a 12-foot-long tube in which the pilot lies flat on his stomach and looks out a plexiglass window while manipulating control levers and cruising at a max speed of three knots.

Rush recalls his first dive in road-to-Damascus terms. “While I was building the sub, I was thinking, This is stupid. I should have just bought a robot and explored with that,” he said. “But the moment I went underwater, I was like, Oh—you can’t describe this. When you go in a sub, things sound different, they look different. It’s like you’ve gone to a different planet.” Rush was hooked—and his entrepreneurial instincts were piqued. “I had come across this business anomaly I couldn’t explain: If three-quarters of the planet is water, how come you can’t access it?”

Our ongoing ignorance of the underwater world is something of a historical accident, Rush discovered. After the Moon landing in 1969, there was a tremendous push for ocean exploration in the U.S. “The thought was, that’s the next frontier,” he says. The Navy pumped millions into manned submersibles with names like *Alvin*, *Turtle* and *Mystic*, with research fueled by secret Cold War missions such as the 1974 recovery of a sunken Russian ballistic-missile sub from the Pacific floor. But in the post-Vietnam recession, government funds dried up. In Seattle, military sub researchers went into other areas of defense con-

tracting and maritime side-specialties such as sonar.

Soon after, the private market died too, Rush found, for two reasons that were “understandable but illogical.” First, subs gained a reputation for danger. Working on offshore rigs in harsh locations like the North Sea, saturation divers, who breathe gas mixtures to avoid diving sicknesses, would be taken in subs to work at great depths. It was the world’s most perilous job, with frequent fatalities. (“It wasn’t the sub’s fault,” says Rush.) To save lives, the industries moved toward using underwater robots to perform the same work.

Second, tourist subs, which could once be skippered by anyone with a U.S. Coast Guard captain’s license, were regulated by the Passenger Vessel Safety Act of 1993, which imposed rigorous new manufacturing and inspection requirements and prohibited dives below 150 feet. The law was well-meaning, Rush says, but he believes it needlessly prioritized passenger safety over commercial innovation (a position a less adventurous submariner might find open to debate). “There hasn’t been an injury in the commercial sub industry in over 35 years. It’s obscenely safe, because they have all these regulations. But it also hasn’t innovated or grown—because they have all these regulations.” The U.S. government, meanwhile, has continued to favor space exploration over ocean research: NASA today gets about \$10.5 billion annually for exploration, while NOAA’s Office of Ocean Exploration and Research is allotted less than \$50 million—a triumph of “emotion over logic,” Rush says. “Half of the United States is underwater, and we haven’t even mapped it!”

Although Rush can sound as if he’s found a semi-religious calling—he is fond of saying things like “I want to change the way humanity regards the deep ocean”—he is also blunt about his interest in responsibly exploiting America’s natural resources, pointing out that the country’s “exclusive economic zone,” which extends as far as 230 miles from every coast, is vast, thanks to U.S. island possessions. There could be massive oil and gas reserves, rare minerals or diamonds—to say nothing of deep-sea corals and other possible sources of rare chemicals that might, for example, lead to medical breakthroughs. “We don’t know what resources are out there.”

Rush’s first dive in his mini-sub had only been to 30 feet, but he had contracted what he calls “the deep disease.” From 2007, he began descending to ever-lower depths, first testing the sub by lowering it on a rope to see if the hull or windows would crack. “I went to 75 feet. I saw cool stuff. I went 100 feet and saw more cool stuff. And I was like, Wow, what’s it gonna be like at the end of this thing?” He began to fantasize about seeing what’s known as the “deep scattering layer” around 1,600 feet, where marine life is so dense that early sonar scans in the 1940s

Rush uses PlayStation controllers to direct *Titan*’s electric thrusters, ballast system and an array of high-definition video cameras for steering.

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A rear camera allows the pilot to dock *Titan* on the submerged platform after completing a dive. The platform and sub are then raised to the surface.

reported it as a false, ever-shifting seafloor. Experts surmise that in the darkness below that there exist more than a million invertebrate species, most still unknown to marine biologists.

Rush commissioned a marketing study and found demand for “participatory” adventure travel to the deep ocean, and the idea was born to take clients on expeditions to pay for developing new sub technology that would have wider commercial applications—scientific exploration, disaster response, resource speculation. Rush and a business partner (who has since left the company) formed OceanGate in 2009.

When the blizzard eased up, I made the slow pilgrimage with Rush in his SUV north to OceanGate’s headquarters, in Everett, creeping along a highway lined with snow-covered pine trees that loomed like icebergs. The waterfront office seemed crisply corporate except for the telltale scale models of the *Titanic* and *Titan* sitting on a shelf. But opening the door to the workshop revealed the company’s hands-on side: an Aladdin’s cave for tech geeks, a jumble of white hulls that looked like shark fins, sculptural engineering parts, oxygen tanks and oddities like a mysterious Perspex sphere whose interior resembled a medieval clock.

There was OceanGate’s first commercial sub, *Antipodes*, which was painted bright yellow and whose array of dials and meters had a steampunk air. “I wish it were a different color—I can’t stand that song,” Rush said of “Yellow Submarine.” In 2010, he used the five-person *Antipodes*, which could descend to 1,000 feet, to carry his first paying clients to Catalina Island, off the coast of California; later, he undertook expeditions to explore corals, lionfish populations and an abandoned oil rig in the Gulf of Mexico. To refine the tourist experience, he decided to recruit expert guides. “People would ask me about a fish, and I wouldn’t know anything about it,” he recalls. So he

brought along marine biologists. “The difference was night and day. Their excitement permeated the sub.”

“Deep disease” now pushed Rush into a new phase: engineering. He abandoned the traditional spherical submersible shape. “It’s the best geometry for pressure, but not for occupation, which is why you don’t have spherical military subs,” he says. Instead, he developed *Cyclops 1*, a cylinder that fits five people and is strong enough to descend to 1,600 feet. The steel hull was acquired in 2013 from a company in the Azores, who had been using it for 12 years. Its interior was entirely revamped by the OceanGate engineering team and the Applied Physics Laboratory at the University of Washington, who helped integrate new underwater sensors and install the Sony PlayStation controllers, which gave the sub a uniquely intuitive piloting system.

The idea of trips to the *Titanic* first arose as a mar-



keting ploy. Shipwrecks, Rush realized, were a way to grab public attention. In 2016, OceanGate mounted an expedition with paying passengers in *Cyclops 1* to the wreck of the *Andrea Doria*, an Italian passenger liner that sank off the coast of Nantucket in 1956, killing 46 people. Media interest spiked. “But there’s only one wreck that *everyone* knows,” Rush says. “If you ask people to name something underwater, it’s going to be sharks, whales, *Titanic*.”

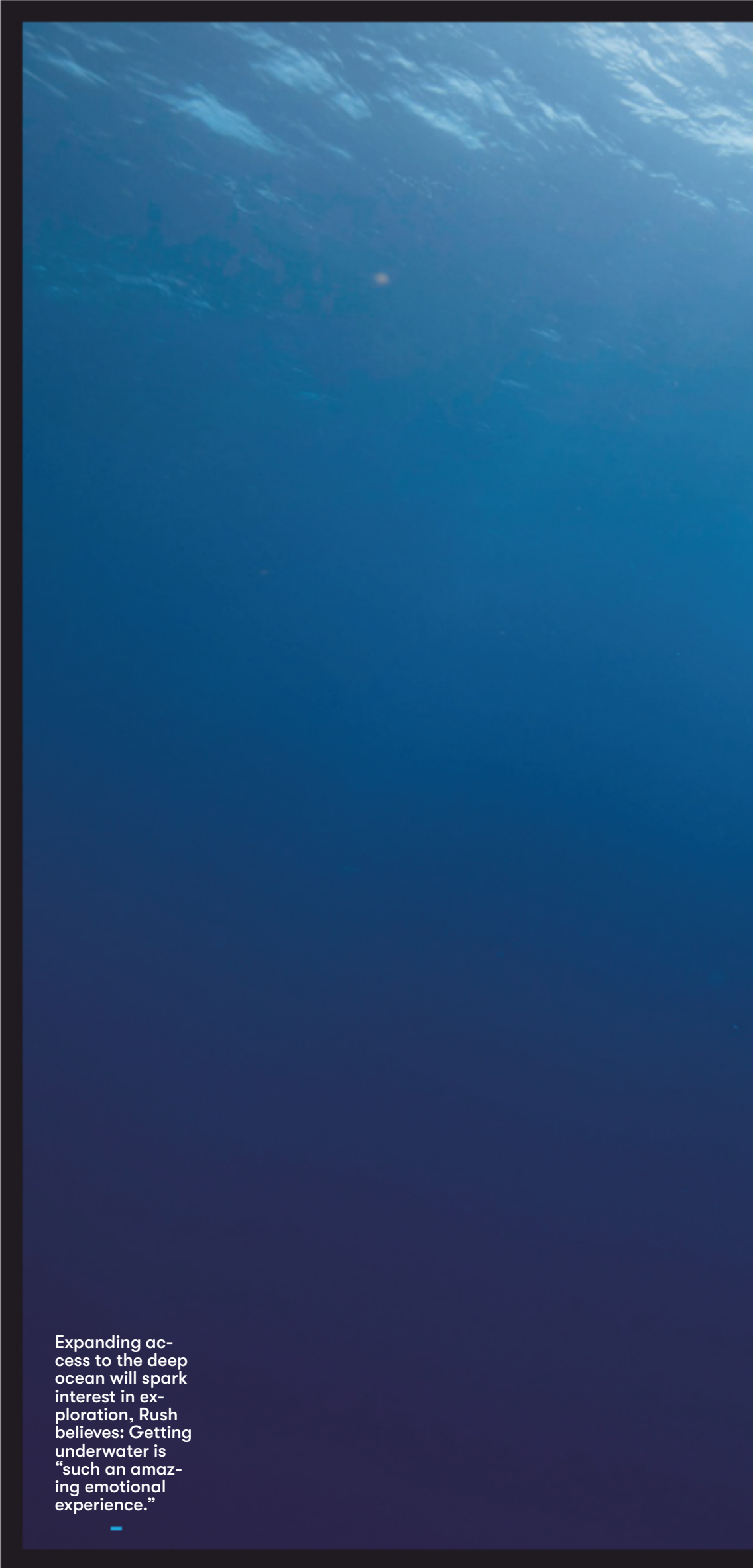
The wreck had been visited by tourists before. More than a decade after the ship was located in 1985, by Robert Ballard, Russia contracted two Mir subs to a company called Deep Ocean Expeditions. (It was also a Mir sub that allowed James Cameron to film the haunting opening scenes of *Titanic*.) A string of salvage missions funded by private investors has also gathered roughly 5,500 *Titanic* relics, including plates, unopened Champagne bottles and the window frame of the Verandah Café. Some 250 items are on exhibition in the Luxor Hotel & Casino in Las Vegas, along with a piece of the hull recovered from the debris field. (In 2012, the wreck came under the protection of Unesco, which has tried to safeguard the site from looting and further damage.)

Even so, fewer than 200 people have been to the *Titanic*, and Rush believes there are still original discoveries to be made. The most exciting possibilities lie in exploring the so-called “debris field,” the scattering of the passengers’ personal effects between the two halves of the ship, which broke apart on the surface as it began to sink. OceanGate’s expeditions are also scheduled to conduct sonar, laser scanning and photogrammetric image capture of the entire vessel, in partnership with a company called Virtual Wonders, with an eye toward creating 3-D and virtual reality films, TV shows, video games and exhibition-based immersive experiences.

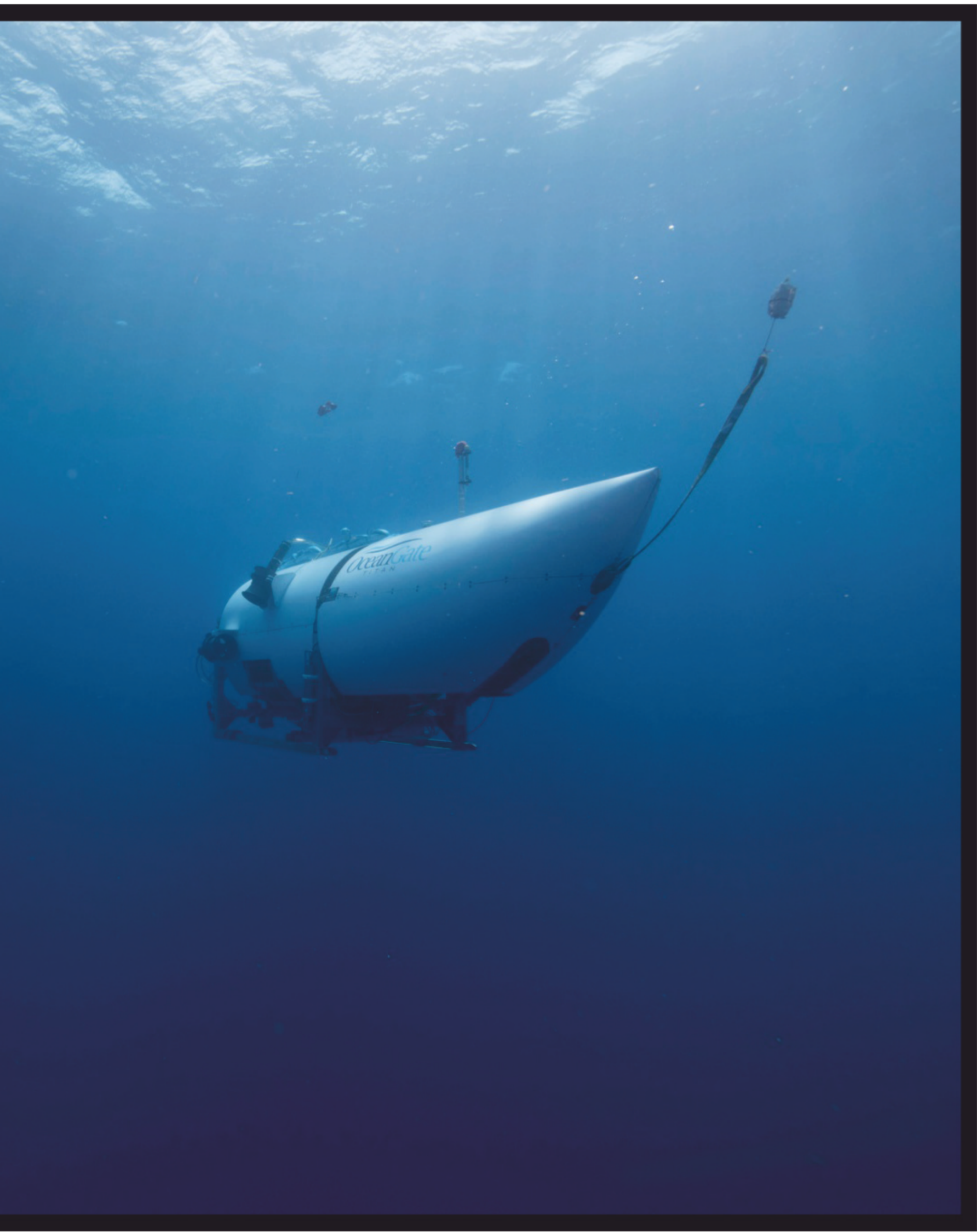
There was only one catch to Rush’s plan: He still had to prove that *Titan* could safely get down to the site.

EVER SINCE 1930, when the American inventor and naturalist William Beebe sank to 800 feet in his “bathysphere,” every deep-sea sub has been made of metal, usually steel or titanium. Rush began to experiment with carbon fiber, a lightweight, extremely strong material long used in the aerospace industry. “We thought, Hey, we can use this stuff to make a really cool sub!”

If it worked, it would be a game changer. The weight of steel and titanium subs makes them expensive to transport on land and requires large ships, outfitted with cranes, to launch at sea. Because of their heft, traditional subs tend to require bulky, syntactic foam flotation blocks to maintain neutral buoyancy, which is crucial for maneuverability. *Titan*, by contrast, is much cheaper to transport and launch, and without the foam is nimbler in the water. *Titan* uses the same sleek frame design, control panels, thrusters and life



Expanding access to the deep ocean will spark interest in exploration, Rush believes: Getting underwater is “such an amazing emotional experience.”





support systems as *Cyclops 1*, carrying 96 hours of oxygen, but it has a smaller and stronger acrylic window and no top hatch. (Passengers enter through the “eye” itself, as the whole front end of the sub swings open.) Latched onto its 35-foot-long launch platform, it’s transported easily to any location. Most important, Rush believed the carbon fiber body was strong enough to resist crushing pressure down to 13,000 feet.

To test the new sub, Rush chose Great Abaco Island, in the Bahamas. Abaco’s unique advantage is that it sits on the edge of the continental shelf. To reach 13,000-foot-deep waters from Seattle, “I’d have to go 300 miles offshore,” Rush explains. From Abaco, *Titan* only needs to be towed 12 miles to have 15,000 feet of water to explore. Delays occurred from the start. In April 2018, *Titan* was in the shipyard just in time for a massive lightning storm that damaged the electrical system, forcing the computers to be replaced. When tests began again in May, an unusual burst of stormy weather postponed the schedule further.

Rush planned to pilot the sub himself, which critics said was an unnecessary risk: Under pressure, the experimental carbon fiber hull might, in the jargon of the sub world, “collapse catastrophically.” So OceanGate developed a new acoustic monitoring system, which can detect “crackling,” or, as Rush puts it, “the sound of micro-buckling way before it fails.” Still, Rush decided to test the hull by lowering the sub to 13,000 feet unmanned. It held.

Last December, the team finally began manned tests, with Rush first dropping 650 feet to the so-called “thermocline,” where tropical water temperature begins to drop precipitously. After successful descents to 3,200, 6,500 and 9,800 feet, *Titan* was finally ready to plunge to the *Titanic*’s depth.

The dive was going according to plan until about 10,000 feet, when the descent unexpectedly halted, possibly, Rush says, because the density of the salt water added extra buoyancy to the carbon fiber hull. He now used thrusters to drive *Titan* deeper, which interfered with the communications system, and he lost contact with the support crew. He recalls the next hour in hallucinogenic terms. “It was like being on the Starship *Enterprise*,” he says. “There were these particles going by, like stars. Every so often a jellyfish would go whipping by. It was the childhood dream.”

He had been so focused on the task that the achievement of reaching 13,000 feet only hit him when he regained contact with his crew during the ascent. He had chosen to pilot *Titan* alone in case anything went unexpectedly wrong, he said. But he also wanted to be only the second person to travel solo to at least that depth, the other being James Cameron, who in 2012 took an Australian-built sub

Rush hopes for an explosion in ocean tech innovation. “Building subs is a lot easier than building airplanes,” he says, “but it’s so unique, nobody knows it.”

into the Mariana Trench, reaching Challenger Deep, the ocean’s deepest point, touching down at close to 36,000 feet. “That’s a nice club to be a part of,” Rush says. Two weeks later, that club welcomed a new member, when a Texas businessman named Victor Vescovo reached 27,000 feet in his own experimental submersible, whose spherical titanium hull is encased in syntactic foam.

ON JUNE 27, OceanGate is scheduled to leave for the first of six trips to the *Titanic* site. This summer’s 54 pioneer clients range in age from 28 to 72, and mostly come from the U.S. and Britain, with a few from Australia, Canada and Germany. These 21st-century Astors and Rockefellers are extremophiles, the types of travelers who in the 19th century might have signed up for Amazon explorations and African safaris. Many have traveled to the Antarctic and the North Pole; some have participated in mock dogfights in MIG planes over Russia.

There will be three dives per expedition, and on each descent, three clients will be accompanied by a pilot (drawn from a roster of three, including Rush) and a scientist or a historian specializing in the wreck’s lore. Each dive will involve about 90 minutes of descent, three hours exploring the wreck, and a 90-minute ascent to the surface.

And the future? When the *Titanic*’s public appeal fades, Rush envisions expeditions to the World War II wrecks in the Coral Sea, to underwater volcanic vents filled with marine life, to deep-sea canyons that no human has ever seen. As for me, the modest dunk in *Cyclops 1* gave me an inkling of “deep disease.” As the sub surfaced, every sight and sound seemed strange and unfamiliar. The waterline receded over the sub’s eye to reveal the snow-covered dock and a layer of floating ice; I felt a slight popping in my ears as the hatch opened.

I thought back to a conversation in which Rush painted a portrait of our long-term future that felt, at the time, like science fiction. “We’re going to colonize the ocean long before we colonize space,” he said. In the event that terra firma becomes uninhabitable, undersea settlements could prove more viable “life boats” than interstellar space. “Why leave?” Rush asked. “The ocean is a very protected environment. It’s safe from ozone radiation, nuclear war, hurricanes. The temperatures and currents are very stable.” The idea was undoubtedly far-fetched, and the technology a long way off, but I had to admit that the experience of breathing and moving so freely underwater had captured my imagination. “Every time I go deeper, the experience gets cooler and cooler,” Rush said. “At the very bottom of the ocean, there must be a bunch of octopuses playing chess, wondering why it’s taken us so long to get there.” ♦

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Apollo 11

CONTINUED FROM PAGE 35

with his big round helmet, when all of a sudden, here he came bounding from foot to foot like a kid at a playground, right at the video camera he and Armstrong had set up at the far side of their landing site.

Aldrin was romping straight at the world, growing larger and larger, and he was talking about how he'd discovered that you have to watch yourself when you start bouncing around, because you couldn't quite trust your sense of balance in Moon gravity; you might get going too fast, lose your footing, and end up on your belly, skidding along the rocky lunar ground.

"You do have to be rather careful to keep track of where your center of mass is," Aldrin said, as if his fellow Earthlings might soon find this Moonwalk advice useful. "Sometimes, it takes about two or three paces to make sure you've got your feet underneath you."

Reihm should have been having the most glorious moment of his career. By the time of the Moon landing, before he turned 30, he had become the Apollo project manager inside Playtex. His team's blazing white suits were taking men on their first walk on another world. They were a triumph of technology and imagination, not to mention politics and persistence. The spacesuits were completely self-contained spacecraft, with room for just one. They had been tested and tweaked and custom-tailored. But what happened on Earth really didn't matter, did it—that's what Reihm was thinking. If Aldrin should trip and land hard on a Moon rock, well, a tear in the suit wouldn't be a seamstress's problem. It would be a disaster. The suit would deflate instantly, catastrophically, and the astronaut would die, on TV, in front of the world.

The TV camera, set up on a tripod, would have a perfect view. Aldrin ran left, planted his left leg, then cut to the right like an NFL running back dodging tacklers. He did kangaroo hops right past the American flag, but announced that this wasn't a good way of moving around. "Your forward mobility is not quite as good as it is in the more conventional one foot after another," he said. Then he disappeared from view.

By this time Reihm could barely contain his fretfulness. "That silly bastard is out there running all over the place," he thought.

Seconds ticked by. The Moon base was quiet. Armstrong was working by the lunar module, his back to the camera. Suddenly Aldrin came dashing in from the left, straight across the landing site, Moon dirt flying from his boots. He was doing a Moon run: "As far as saying what a sustained pace might be, I think the one that I'm using now would get rather tiring after several hundred feet."

Reihm was in a technical support room adjacent to Mis-

sion Control, with a group of spacesuit staff, standing by in case anything went wrong. Even though the whole point of the spacesuits was to explore the Moon, Reihm couldn't wait for it to end.

Reihm's worries weren't unique to him. Eleanor Foraker had supervised the women who sewed the spacesuits, each painstakingly stitched by hand. When the jumping around started, she started thinking about the pressure garment, one of the inner layers of the spacesuit that sealed the astronaut against the vacuum of space. What if all that hopping and tugging caused a leak?

Joe Kosmo was one of the spacesuit designers on the NASA side. He was at home, watching with his family, thinking exactly the same thing Reihm was: "This is great. I hope he doesn't fall over."

Reihm knew, of course, that the astronauts were just out there "euphorically enjoying what they were doing." If the world was excited about the Moon landing, imagine being the two guys who got to do it. In fact, according to the flight plan, right after the landing, Armstrong and Aldrin were scheduled for a five-hour nap. They told Mission Control they wanted to ditch the nap, suit up and go outside. They hadn't flown all the way to the Moon in order to sleep.

And there really wasn't anything to worry about. The spacesuits were marvels: 21 layers of nested fabric, strong enough to stop a micrometeorite, but still flexible enough for Aldrin's kangaroo hops and quick cuts.

Still, watching Aldrin dash around, Reihm could "think of nothing but, Please go back up that ladder and get back into the safety of that lunar module. When [they] went back up that ladder and shut that door, it was the happiest moment of my life. It wasn't until quite a while later that I revealed over the accomplishment."



Buzz Aldrin, who photographed his footprint in the lunar soil, later poked fun at his historic walkabout: "Location, location, location!"

THE APOLLO 11 SPACESHIP that carried Michael Collins, Buzz Aldrin and Neil Armstrong from the Earth to the Moon was big: The command and service module and the lunar module, docked nose-to-nose, was 53 feet long. When Collins fired the service module engine to settle into orbit around the Moon—the big engine ran for 357.5 seconds to slow the ship, six long min-

utes—there was already another spaceship in orbit around the Moon waiting for them. It had arrived two days earlier, from the Soviet Union.

Luna 15 was a Russian unmanned robotic craft that was at the Moon on a mysterious mission. It was certainly no coincidence that at the moment the United States was getting ready to land people on the Moon's surface, with the whole world watching, the Russians had decided to have a spacecraft at the Moon. Luna 15 had been launched on Sunday, July 13, before the Wednesday launch of Apollo 11, and the Russians said it

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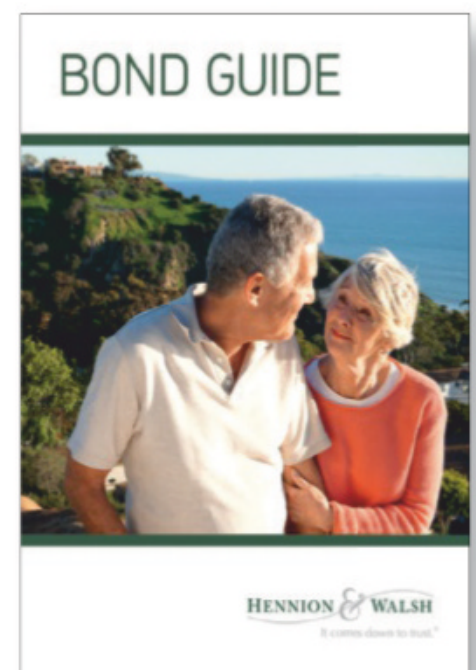
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was simply going to “conduct further scientific exploration of the Moon and space near the Moon.”

But from the moment of Luna 15’s launch, U.S. space scientists and NASA officials speculated that it was a “scooping” mission, designed to land on the Moon, extend a robotic arm, scoop up some soil and rocks, and deposit them in a compartment on the spacecraft, which would then zoom back to Earth and maybe, just maybe, arrive back on Russian soil with its cargo before the Apollo 11 astronauts could make it home.

Frank Borman, the commander of the Apollo 8 mission that had orbited the Moon, had just returned from a nine-day goodwill tour of Russia—the first visit by a U.S. astronaut to the Soviet Union—and appeared on the NBC news show “Meet the Press” the morning of Luna 15’s launch. “I would guess it’s probably an effort” to bring back a soil sample, Borman said. “I heard references to that effect [in Russia].”

NASA, at least publicly, was mostly concerned that Russian communications with Luna 15 might interfere with Apollo 11. In an unprecedented move, Chris Kraft, the head of Mission Control, asked Borman to call Soviet contacts from his just-finished trip and see if they would supply data on Luna 15. The Soviets promptly sent a telegram—one copy to the White House, one copy to Borman’s home near the Manned Spacecraft Center—with details of Luna 15’s orbit and assurances that if the spacecraft changed orbits, fresh telegrams would follow. It was the first time in the 12 years of space travel that the world’s two space programs had communicated directly with each other about spaceflights in progress. At a press conference, Kraft said Luna 15 and the Apollo spacecraft would not come anywhere near each other.

Luna 15, at least to start, succeeded in making sure the Soviet Union’s space program wasn’t overlooked while Apollo 11 dominated the news worldwide. The Soviet mission made the front pages of newspapers around the world. At the time, NASA and the public never did find out what Luna 15 was up to. Now we know it was a well-planned effort to upstage Apollo 11, or at least be onstage alongside the U.S. Moon landing, according to documents released and research done since the breakup of the Soviet Union and thanks to the rich and detailed history of the Soviet space program written by historian Asif Siddiqi, *Challenge to Apollo*.

When Luna 15 arrived in lunar orbit on July 17, two days ahead of Apollo 11, Siddiqi says, Russian space officials were surprised “by the ruggedness of the lunar terrain” where it was headed, and that the craft’s altimeter “showed wildly varying readings for the projected landing area.” As Armstrong and Aldrin stepped out onto the lunar surface, Luna

SUDDENLY
ALDRIN CAME
DASHING
IN FROM
THE LEFT,
STRAIGHT
ACROSS THE
LANDING SITE,
MOON DIRT
FLYING FROM
HIS BOOTS.

15 was still swooping around the Moon, and engineers back in the Soviet Union were still trying to find a landing site they had confidence in.

Two hours before the Eagle, with Armstrong and Aldrin aboard, blasted off the Moon, Luna 15 fired its retro-rockets and aimed for touchdown. The legendary British radio telescope at Jodrell Bank Observatory, presided over by Sir Bernard Lovell, was listening in real time to the transmissions of both Apollo 11 and Luna 15. And Jodrell Bank was the first to report the fate of Luna 15. Its radio signals ended abruptly. “If we don’t get any more signals,” said Lovell, “we will assume it crash-landed.” Luna 15 was aiming for a site in the Sea of Crises, about 540 miles northeast of Eagle’s spot in the Sea of Tranquillity.

The Soviet news agency Tass reported that Luna 15 had fired its retrorockets and “left orbit and reached the Moon’s surface in the preset area.” Its “program of research . . . was completed.”

Despite taking almost a whole extra day to figure out the terrain issues, Soviet space scientists apparently missed a mountain in the Sea of Crises. On its way to the “preset area,” Luna 15, traveling 300 miles per hour, slammed into the side of that mountain.

At about 1:15 p.m. Eastern time Tuesday, the Apollo astronauts woke from a 10-hour rest period and were 12 hours into their 60-hour ride back from the Moon. As they got started on their day, astronaut Bruce McCandless, Mission Control’s official Capsule Communicator, radioed, “Apollo 11, this is Houston. If you’re not busy now, I can read you up the morning news.”

Replied Aldrin, “Okay, We’re all listening.”

A lot of the news was about Apollo 11. Reported McCandless, “Things have been relatively quiet recently in Vietnam. G.I.s on patrol were observed carrying transistor radios tuned to your flight.”

About one-third of the way through McCandless’ space newscast, slipped in between telling the astronauts that President Nixon would head to Romania after meeting them onboard their recovery aircraft carrier, and the Vietnam news, McCandless reported, “Luna 15 is believed to have crashed into the Sea of Crises yesterday after orbiting the Moon 52 times.”

If ever there was a moment that captured the crushing reversal in the performance of the world’s two space programs, that was it: Mission Control matter-of-factly reporting the crash-landing of the Soviet Union’s somewhat flailing robotic attempt to collect Moon rocks to the three American astronauts flying home from the first human landing on the Moon, with 47.5 pounds of Moon rocks. ♦

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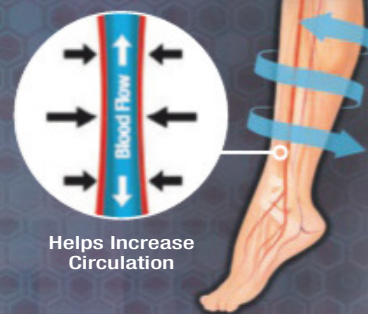
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Toledo

CONTINUED FROM PAGE 45

body, pull-toys, and laser cuts of insects, including a large black scorpion.

"Right now, I am doing self-portraits. I started doing self-portraits first when I had no money. But I had a mirror! I couldn't do nudes. They said, 'You're too young.' I made a self-portrait yesterday—not one, many. I make ten or more at a time."

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"Recently some people in Mérida asked me to do some pictures of pyramids. I've been doing that, lots of them."

He opened a chest in which booklets were piled. I took them to be children's books, but he explained that they were stories he had illustrated.

"I'm a publisher, too," he said. "I published these—I want to publish more."

I picked up a few and leafed through them, and was impressed by the care with which they had been printed: lovely designs, beautiful typefaces, glowing illustrations—of fabulous animals, jungle foliage, witchlike faces with intimidating noses.

"Maybe you can write a story for me," he said. "I'll make a picture. I'll publish it."

"I'll write one, as soon as I have an idea."

"Good, good," he said, and we shook hands. Then he hugged me, and in a whirl—his bouncing gait, his wild hair—he was gone.

Sometime after that a Mexican friend of mine, strolling in Oaxaca, saw Toledo hurrying to his library. He said hello and mentioned my visit.

"He's a good gringo," Toledo said. You can't have higher praise than that in Mexico. But my friend had more to report. He texted his fiancée in Mexico City: I just saw Toledo."

"*Pide un deseo*," she texted back. "Make a wish." Because any encounter with this powerful man, or his work, was lucky, magical, an occasion to celebrate. ♦

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Human Computers

CONTINUED FROM PAGE 14

notes Paul Ceruzzi, author of *Reckoners: The Prehistory of the Digital Computer*. Decades later, one human computer—Marilyn Heyson—recalled the job as intellectually interesting, but a marathon. “I had moments when I said, ‘Did I go to college for this job?’” she told Sarah McLennan, an assistant professor at Virginia State University.

In World War II, the need for computation exploded. Over 200 women were hired at the University of Pennsylvania’s Moore School of Electrical Engineering, creating artillery-trajectory tables for the Army. By 1944, as Grier documents, about half of all computers were women. One contractor of the Applied Mathematics Panel used the term “kilogirl” to refer to 1,000 hours of female calculation work. Another astronomer spoke of “girl-years” of work.

Few expected that computing would lead to a career, though. The idea was, mostly, to use the women before they married. Astronomer L. J. Comrie wrote a 1944 *Mathematical Gazette* article entitled “Careers for Girls,” in which he declared that female computers were useful “in the years before they (or many of them) graduate to married life and become experts with the housekeeping accounts!”

AFTER THE WAR ENDED, the space race was on, and it had a ravaging need for computation—crunching numbers on projects like wind-tunnel tests of wings. The National Advisory Committee for Aeronautics, or NACA (the precursor to NASA), hired several hundred women as computers at its Langley base in Virginia, the historian Beverly Golemba estimated. NACA and NASA were relatively progressive employers, paying the young women far better than they’d get in other forms of office work; they even employed married women with children.

One woman who stumbled into the field in the late 1950s was Sue Finley. “I loved math,” she tells me. She studied logic in college and was disenchanted with the sales and typing jobs on offer after she graduated. One day, while applying at an engineering firm, she was offered work as a computer, and found joy in its rigor and

puzzle-solving. Later, she landed a computing job with NASA's Jet Propulsion Laboratory, where she labored all day using a clattering, breadbox-size electric Friden calculating machine.

It was, she says, a remarkably egalitarian oasis in 1950s America. "The engineers, the male engineers, always listened to us," she notes.

At its bases, NASA employed nearly 80 black women as computers, says Margot Lee Shetterly, author of *Hidden Figures*. One of them, Katherine Johnson, was so revered for her abilities that in 1962, John Glenn asked her to personally verify the flight path of his first launch into space on the Friendship 7 mission. The astronauts didn't trust the newfangled digital computers, which were prone to crashing. Glenn wanted human eyes on the problem.

"They had a tremendous amount of respect for these women and their mathematical abilities," says Shetterly. "The male engineers often were not good mathematicians. So the women made their work possible." Still, some friction existed. Women who asked for promotions got stonewalled or turned down: "For women who wanted to move up, who wanted to be supervisors—particularly if that involves supervising men? Not so much."

Soon, the human computers faced an even more existential threat: digital computers, which promised to work with far greater speed and to handle complex math—like inverting a 10x10 matrix—beyond the ken of even the most adroit human with a pencil.

Women, though, were among the original coders of these strange new digital brains, because in the early days programming, too, was seen as dull work. The earliest programmers for the Eniac—the military-funded first programmable general-purpose computer—were entirely women, plucked from the ranks of the Army's human computers. And though they wound up inventing brilliant coding techniques, they received none of the glory: When the Army showed off the Eniac to the press, running lightning-fast ballistics-crunching algorithms, it didn't introduce the women who'd written the code.

By the '60s and '70s, human computa-

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tion was dying. But some women made the transition to the new world of software—including Sue Finley. After taking a weeklong course on the language Fortran, she began a decades' long career coding on NASA's space missions, including software that tracked probes to Venus. At 82, she remains at work as an engineer in the Deep Space Network; she also works on entry, descent and landing of spacecraft and still thrills to the mental challenge of debugging some gnarly problem in the code that peers into space.

"It's a mystery, solving a mystery," she tells me. "It's fun when it's successful."

IN ONE SENSE, the story of female computers stands in appealing contrast to the difficulties faced by women in coding today. After all, even in the more straightforwardly sexist decades of the 19th and early 20th centuries, women were accepted and even sought out for their skills. Why is it worse now? Finley sometimes talks to young women in software, and is appalled by their tales of harassment and having their work denigrated.

Research by Sue Gardner, the former head of the Wikimedia Foundation, has found that women in the software industry often leave in mid-career; they start off excited and happy, but after a decade are ground down. Finley understands. "Why would anybody want to work in those circumstances or go into that field?" she asks rhetorically.

Though women programmers have made strides in some fields—such as "front-end" programming, for browser applications—the salaries in those specialties tend to be lower overall, simply because the industry regards anything being done by women as easy, according to Miriam Posner, an assistant professor of computer science at UCLA. It is becoming a pink-collar ghetto in coding, Posner notes, rather like the status of female human computers.

Tracy Chou is cautiously optimistic. There's certainly more conversation these days in Silicon Valley about the need to hire and promote women as readily as men. "Hopefully, some of the public posturing does end up forcing people to do something," she says wryly. Calculations can be solved once and for all; social problems are harder. ♦

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Q: Why can't we use energy from volcanoes like the one at Yellowstone to generate electricity? Iceland is almost totally powered by volcanoes.

Jamie Sorensen | Denver

IT'S CERTAINLY a tempting idea. Yellowstone has the largest concentration of geysers on earth and scientists estimate that it has enough geothermal energy to power the whole country. But it's not possible with today's technology to harness and distribute all that energy, says Liz Cottrell, a geologist at the National Museum of Natural History. And since 1970, the park, a Unesco World Heritage site, has been legally protected from potentially damaging geothermal plants. When New Zealand built a geothermal plant near Wairakei Basin in the 1950s, it ended up destroying the area's 70 geysers and 240 of its hot springs. Iceland avoided this fate because its hot fluids are so close to the surface, and because the entire country rebuilt its infrastructure, starting in the 1970s, with geothermal energy in mind.



Submit your queries at [Smithsonian.com/ask](https://www.smithsonian.com/ask)

Q: How did Albert Einstein contribute to the Manhattan Project?

Anonymous | Beaufort, South Carolina

MOSTLY WITH HIS signature, says Roger Sherman, associate curator of the modern physics collection at the National Museum of American History. In 1939, Einstein signed a letter, prepared along with the physicist Leo Szilard and addressed to President Roosevelt, that discussed uranium fission and the possible use of atomic bombs in war. Though Einstein later called the letter his greatest mistake, he also said, "There was some justification—the danger that the Germans would make them." His primary contribution to the war effort was studying and developing underwater weapons for the U.S. Navy's Bureau of Ordnance.

Q: Do tigers and other large felines purr like domestic cats?

Rob Loughridge | Honolulu

MOST BIG cats can't purr, explains Craig Saffoe, curator of the Great Cats area at the National Zoo. In lions, tigers and other such felines, the hyoid apparatus, which supports the larynx and tongue, is mostly cartilage. When air pushes through the throat, the vibrations come out as booming vocalizations, like bellows or roars. In domestic cats, the hyoid apparatus is mostly bone, which leads to softer, purring vibrations. Some smaller wild cats share this trait, which means cheetahs and cougars can purr.

Q: How and when did scientists figure out space was a vacuum?

Brooke C. Stoddard | Alexandria, Virginia

IT ONLY TOOK a couple of millennia, jokes David DeVorkin, senior curator at the National Air and Space Museum's Space History Division. The pre-Socratic Greek philosophers first theorized the concept of a vacuum. In the 17th century, Blaise Pascal and other scientists experimented with barometers and saw that pressure diminishes as altitude climbs. Starting in the 1940s, ballooning and rocketry became more sophisticated, and scientists observed that the lower the satellite, the more likely it was to experience atmospheric drag. In the 1964 Echo 2 project, NASA sent a mostly flattened balloon with very little gas into space. When the balloon was released from the satellite capsule, it blew up to 135 feet in diameter, signaling incredibly low pressure. There's no such thing as a perfect vacuum, but space is a close approximation. ♦

Text by Anna Diamond

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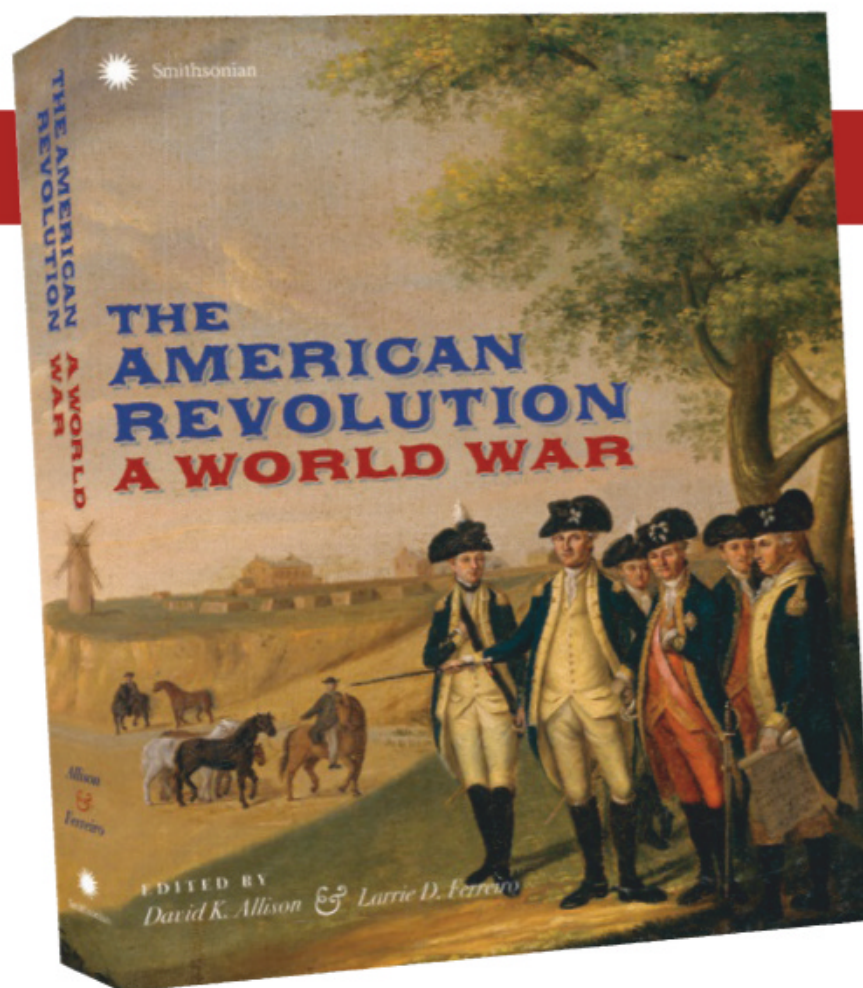
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